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**APPLICATION NUMBER: 60/053,211**

**FILING DATE: July 21, 1997**

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04934 U.S. PIU  
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PTO/SB/46 (6-95)  
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## PROVISIONAL APPLICATION COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION under 37 CFR 1.53 (b)(2).

Docket Number			Type a plus sign (+) inside this box →	+
INVENTOR(S)/APPLICANT(S)				
LASTNAME	FIRSTNAME	MIDDLE INITIAL	RESIDENCE (CITY AND EITHER STATE OR FOREIGN COUNTRY)	
Sogaard	Morten		Copenhagen, Denmark	
TITLE OF THE INVENTION (250 characters max)				
DIRECTED CYTOLYSIS OF TARGET CELLS, AGENTS AND COMPOSITIONS CAUSING CYTOLYSIS, AND COMPOUNDS THAT CAN BE USED TO PRODUCE THE AGENTS				
CORRESPONDENCE ADDRESS				
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STATE	TX	ZIP CODE	77027-9095	COUNTRY U.S.A.
ENCLOSED APPLICATION PARTS (check all that apply)				
<input checked="" type="checkbox"/> Specification	Number of Pages	56	<input type="checkbox"/> Small Entity Statement	
<input checked="" type="checkbox"/> Drawing(s)	Number of Sheets	11	<input type="checkbox"/> Other (specify)	
METHOD OF PAYMENT (check one)				
<input checked="" type="checkbox"/> A check or money order is enclosed to cover the Provisional filing fee				PROVISIONAL FILING FEE AMOUNT (\$)
<input checked="" type="checkbox"/> The Commissioner is hereby authorized to charge filing fees and credit Deposit Account Number:	16-2435			150.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.

☒ No.

☐ Yes, the name of the U.S. Government agency and the Government contract number are: \_\_\_\_\_

Respectfully submitted,

SIGNATURE

Date 7/21/97

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P40,612

☐ Additional inventors are being named on separately numbered sheets attached hereto

## PROVISIONAL APPLICATION FILING ONLY

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DIRECTED CYTOLYSIS OF TARGET CELLS, AGENTS AND COMPOSITIONS  
CAUSING CYTOLYSIS, AND COMPOUNDS THAT CAN BE USED TO PRODUCE  
THE AGENTS.

Field of the invention

- 5 The present invention relates to inactivation/cytolysis of target cells caused by T cells activated by functional superantigens. Cytolysis can be applied to therapy and to in vitro assays.

10 Definitions

- Superantigens. According to the very first definition (around 1988-1993), superantigens are bacterial or viral proteins capable of binding to MHC class II antigens without prior intracellular processing and activate T cells by binding to the Vbeta-chain variable region (Vbeta) of the T cell receptor (TCR). The binding leads to a Vbeta family restricted activation of a relatively large proportion/subset of T cells and lysis of MHC Class II expressing cells (superantigen dependent cell-mediated cytolysis = SDCC). Normally the superantigen activated subset of T cells constitutes about 1-30% of the total amount of T cells of an individual.

- Well known wild-type superantigens according to the definition above are the staphylococcal enterotoxins (SEA, SEB, SEC1, SEC2, SED, SEE and SEH). Further examples are Toxic Shock Syndrome Toxin 1 (TSST-1, also of staphylococcal origin), Exfoliating Toxins (EXft), Streptococcal Pyrogenic Exotoxin A, B and C (SPE A, B and C), Mouse Mammary Tumor Virus proteins (MMTV), Streptococcal M proteins, Clostridial Perfringens Enterotoxin (CPET), mycoplasma arthritis superantigens etc. For a review of superantigens and their properties see Kotzin et al 1993.

- Wild-type and chimeric superantigens have also been mutated to have a reduced or no MHC class II binding and/or TCRVbeta binding (Kappler et al WO 9314264; Kappler et al 1993; Blanco et al; Abrahmsén et al., WO9601650; Antonsson et al PCT/SE97/00537; Antonsson et al 1997). This type of

superantigens becomes less toxic. In case they completely lack ability to bind to MHC class II or to TCRVbeta they no longer are functional superantigens because they then lose their T cell activating ability.

- 5 By mutating structurally similar wild-type superantigens it has been possible to construct chimeric functionally active superantigens (hybrid superantigens) (Lamphaer et al., 1996 and Antonsson et al PCT/SE97/00537).

It has been discovered that activation and subsequent cell  
 10 lysis can occur in a MHC class II independent manner in case the wild-type superantigen was conjugated with a target-seeking moiety capable of binding to a cell surface structure (Dohlsten et al WO9201470). This novel effector mechanism has been termed superantigen antibody dependent cell-mediated cytotoxicity (= SADCC). It includes the analogous mechanisms for targeting  
 15 moieties other than antibodies (Abrahmsén et al., WO9601650; Antonsson et al PCT/SE97/00537).

Accordingly the superantigen concept of today encompasses any compound (preferably of polypeptide structure) that without  
 20 intracellular processing is capable of binding to a cell surface structure (target structure) and to one or more polymorphic TCR chains, in particular the Vbeta chain, thereby activating a subset of T cells expressing the specific TCR chain involved in the binding. The T cells then become  
 25 cytotoxic and direct their cytotoxicity against cells carrying the surface structure (target structure, target cells). The definition of superantigen (SAG) as used in the context of the invention and if not otherwise specified thus will encompass conjugates between a targeting moiety and a free superantigen  
 30 as discussed above for SADCC.

By the term superantigen is contemplated, if not otherwise specified, only functional superantigens.

A free superantigen (Sag) is a wild-type, possibly mutated or otherwise modified, superantigen that is not conjugated to a  
 35 targeting moiety or to an immune modulator. The MHC class II binding ability of free superantigens is an inherent targeting

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property. Since free superantigens lack conjugated targeting moieties they will only exert SDCC.

A conjugated superantigen is a conjugate between a free superantigen and a targeting moiety or an immune modulator. A conjugated superantigen exerts either or both of SDCC and SADCC.

An immune modulator (IM) is a compound capable of regulating the immune system. In the context of the invention superantigens are treated separately and are not included when the term immune modulator is used. An immune modulator often has an inherent targeting ability, such as for a corresponding lymphocyte receptor. Unless otherwise specified, an immune modulator is in un-conjugated form.

A targeting moiety (T) is a moiety that is capable of binding to a cell surface structure and/or a tissue structure.

A conjugate is composed of two or more moieties Sag, IM, T etc that are linked to each other covalently.

By soluble forms of active ingredients means forms that are soluble in body derived fluids such as serum and plasma.

#### BACKGROUND ART - THERAPEUTIC USE OF SUPERANTIGENS

Non-conjugated wild-type and mutated superantigens have been suggested for therapy with curative effect presumably being accomplished through an activation of the immune system, either locally at Class II expressing cells associated with the disease to be treated or as a systemic activation (Kalland et al WO9104053; Terman et al WO9110680 and WO9324136; Antonsson et al PCT/SE97/00537; and Newell et al 1991). Due to the extreme toxicity of wild-type superantigens this approach, with respect to cancer treatment, should only be applicable to a very minor fraction of all cancers.

It has also been suggested to use superantigens conjugated to target-seeking moieties (Dohlsten et al WO9201470; Abrahmsén et al WO9601650, Antonsson et al PCT/SE97/00537 and Ochi et al 1993), all three publications being incorporated by reference).

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In connection with studies on prevention of superantigen induced down-regulation of T cell mediated cytotoxic activity by IL-2 in vivo it has been speculated that it should be beneficial to coadminister IL-2 with unconjugated wild-type superantigens and wild-type superantigens conjugated to antibodies (Belfrage Thesis Augusti/September 1996; Belfrage et al 1994; Belfrage et al 1995; Belfrage et al 1997a; Belfrage et al 1997b (wild-type superantigens))

It has also been suggested that cell membrane anchored CD80 has a role in superantigen activation of T cells in the absence of MHC class II antigens (Lando et al 1993 and 1996).

Figure 4 in Lando et al 1996 shows an experiment in which the ability of superantigen conjugated to an antibody alone or in combination with IL-2 to induce proliferation of resting human T cells was analyzed. In this 4-day experiment the conjugated superantigen was presented on parent CHO-cell and CHO-cells transfected to express Class II or C215 or Class II plus C215. The effect of IL-2 was insignificant.

Kappler et al (WO9314634) have suggested non-conjugated wild-type SEB mutated to have lost its Vbeta or MHC Class II binding ability (in the context of vaccines and as an agent to neutralize toxic effects of superantigens). Abrahmsén et al (WO9601650) have suggested cancer therapy with conjugated superantigens having a modified, preferably decreased, ability to bind to Class II antigens. Antonsson et al (PCT/SE97/00537) has suggested therapy with chimeric superantigens and superantigens with reduced seroreactivity (see also Abrahmsén et al). Mutations as described by Abrahmsén et al (WO9601650) and Antonsson et al (PCT/SE97/00537) will implicate superantigens with a lowered systemic toxicity, lowered immunogenicity and/or lowered seroreactivity in the mammal to be treated

Therapy with administration of nucleic acids encoding wild-type superantigens have been suggested (Terman et al WO9110680; WO9324136) and Dow et al WO9636366). Dow et al go further on and suggest coadministration of a nucleic acid encoding a

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cytokine or a chemokine with a nucleic acid encoding a superantigen. Without enabling experimental support, WO9636366 also suggests constructs in form of a biscistronic gene construct in which one cistron contains the gene coding for the superantigen and the other cistron contains the gene coding for a cytokine or a chemokine.

Without enabling experimental support Pouletty P (Sangstat, EP 510949) has speculated that conjugates between targeting moieties, such as IL-2, and wild-type superantigens might be useful for inactivating cells expressing the IL-2 receptor.

**BACKGROUND ART - THERAPEUTIC USE OF IMMUNE MODULATORS IN COMBINATION WITH ANTIBODIES SPECIFIC TO CELLS THAT ARE TO BE INACTIVATED.**

It previously has been suggested to conjugate antibodies with biological response modifiers, for instance a chemokine or a cytokine, such as interleukin-2 (Fell et al EP 439095; Rosenblum et al EP 396387, Pancook et al 1996; and Becker et al 1996).

**20 THE PROBLEM THE PRESENT INVENTION SETS OUT TO SOLVE.**

The present invention sets out to provide improvements in relation to superantigen therapy involving activation of the immune system in order to inactivate undesired target cells in a mammal to be treated. In particular the improvements relate to: 1. extending the activation period locally, for instance in a tumour, during a first treatment cycle; 2) counteracting the appearance of hyporesponsiveness due to the tendency of activated T cells to escape into anergy; 3) facilitating MHC class II independent T cell activation in the tumor area; and 4) broadening the therapeutic window for cytotoxicity via superantigen activation. It has now been discovered that these improvements wholly or partly may be accomplished provided that the administration of the superantigen (SAG) is combined with the administration of an immune modulator in soluble form, at least one of the superantigen and the immune modulator being in

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form of a conjugate with a moiety having targeting properties for the cell to be inactivated.

**THE FIRST MAJOR ASPECT OF THE INVENTION: A METHOD OF INACTIVATING  
5 TARGET CELLS.**

The first aspect of the invention covers both therapy and assays in vitro and is a method for inactivating undesired target cells in the presence of T cells by bringing the two types of cells in contact with a superantigen (SAG), in particular a superantigen that activates T cells through binding to TCRVbeta, in the presence of an immune modulator (IM) that is not a superantigen (Sag). In its broadest aspect the method is characterized in that it at least one of the superantigen and the immune modulator is in form of a conjugate with a moiety (T) having targeting properties for the cell to be inactivated. In a subaspect the method is characterized in that

- a. the superantigen (SAG) and the immune modulator is used in form of a triple conjugate comprising a superantigen (Sag), a targeting moiety (T) for the target cells and an immune modulator (IM) (T,IM,Sag-conjugate);
- b. the superantigen (SAG) is used in form of a dual conjugate between a superantigen (Sag) and a targeting moiety (T) for the target cells in combination with a dual conjugate between an immune modulator (IM) and a targeting moiety (T') for the target cells (T,Sag-conjugate + T',IM-conjugate);
- c. the superantigen (SAG) is used in form of a dual conjugate between a superantigen (Sag) and a targeting moiety (T) for the target cells and the immune modulator (IM) is used in free form, i.e. not conjugated to a targeting moiety for the target cells (T,Sag-conjugate + IM);
- d. the superantigen (SAG) is used in free form (Sag) and the immune modulator is used in conjugate form, i.e. a dual conjugate between the immune modulator (IM) and the superantigen (Sag) (Sag + T,IM-conjugate); and

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e. the superantigen (SAG) and the immune modulator is used in form of a dual conjugate between a superantigen (Sag) and an immune modulator (IM) (Sag,IM-conjugate);

The superantigen and the immune modulator may be targeted to the same type of cells, for instance to identical or crossreacting structures/epitopes or to different type of cells within the same tissue. Targeting may be for normal cells or diseased cells associated with one and the same tissue. Either or both of the superantigen and the immune modulator may be targeted with one or several antibodies.

The diseases to be treated by the method of the invention.

The diseases to be treated are in principle the same as those previously suggested for superantigens. See for instance under headings "Background...." above. Illustrative examples are cancers, autoimmune diseases, parasitic infestations, viral infections and other diseases associated with cells that on their surface express MHC class II antigens and/or other structures that are specific for respective disease and bind to the target-seeking moiety incorporated in the superantigen in accordance with the inventive concept (formula I). Also bacterial infections may be combated by the use of the invention.

Important cancer forms in the context of the invention are: melanomas, carcinomas, hematopoietic neoplasias and fibrosarcomas and includes specific forms such as squamous cell carcinoma, breast cancers, head and neck carcinomas, thyroid carcinomas, soft tissue carcinomas, bone sarcomas, testicular cancer, prostatic cancer, ovarian cancers, bladder cancers, skin cancers, brain cancers, angiosarcomas, hemangiosarcomas, mast cell tumors, primary hepatic cancers, lung cancers, cervix cancers, renal cell carcinomas, leukemias and lymphomas. Included are any type of malignant or benign tumors as well as multi-drug resistant cancers, metastatic cancers, various forms of chemically or virally (herpes, SV40, HIV etc) induced cancers.

THE SECOND MAJOR ASPECT OF THE INVENTION: INVENTIVE SUPERANTIGEN CONJUGATES.

This aspect of the invention comprises conjugates complying with the formula



T is a targeting moiety, Sag corresponds to a free superantigen and IM is an immune modulator that is not a superantigen. T, Sag and IM are linked together via organic linkers B that may be different or equal within one and the same conjugate molecule or substance. Conjugates according to formula I encompass chemical conjugates as well as recombinantly produced conjugates (fusion proteins). x, y and z are integers that typically are selected among 0-10, such as 0-5, and represent the number of moieties T, Sag and IM, respectively, in a given conjugate molecule, with the provision that  $y > 0$  and also one or both of x and  $z > 0$ . Chemical conjugates are normally conjugate substances containing a mixture of different conjugate molecules. Accordingly in chemical conjugate substances x, y and z may also be non-integers within the range 0-10, such as within the range 0-5.

In a first subaspect of formula I, Sag and IM and T are present in the conjugate ( $x$  and  $y$  and  $z > 0$ ; T,Sag,IM-conjugates). x, y, and z are typically integers 1-3, with preference for 1-2. Typical relations between x, y and z are:  $x = y = z$ ;  $x = y = 0.5z$ ;  $x = 0.5y = 0.5z$ ; and  $x = 0.5y = z$ .

In a second subaspect of conjugates according to formula I, the targeting moiety is absent (IM,Sag-conjugates,  $x = 0$ ). y and z typically are integers 1-3. Preferred relations between x and y are:  $x = y$ ;  $x = 0.5y$ ,  $0.5x = y$ ;  $x = 1/3y$  and  $1/3x = y$ .

In both subaspects integers or relations primarily refer to fusion proteins in which the targeting moiety may be a protein containing 1, 2, 3 or 4 polypeptide chains and in which there are one T in each conjugate molecule.

Formula I for conjugates according to the second subaspect reduces to :

(Sag)<sub>y</sub>(IM)<sub>z</sub>      Formula II

This type of conjugates are primarily adapted to the treatment of diseases associated with cells expressing MHC class II antigens, in particular class II expressing cancers, such as  
 5 cancers of the hematopoietic system, and certain autoimmune diseases, viral infections and parasitic infestations, but also with diseases associated with cell membrane anchored receptors for the immune modulator, for instance T cell lymphoma expressing for instance the IL-2 receptor.

10

## A. THE IMMUNE MODULATOR IM IN FORMULA I

IM stands for an immune modulator that is not a free or conjugated superantigen.

The immune modulator may be a cytokine or a chemokine.

15 Illustrative cytokines are granulocyte macrophage colony stimulating factor (GM-CSF), tumor necrosis factor alpha or beta (TNFalpha or TNFbeta), macrophage colony stimulating factor (M-CSF), granulocyte stimulating factor (G-CSF), IL-1, IL-2, IL-4, IL-6, IL-7, IL-12, IL-15, IL-18 and IGF.

20 Illustrative chemokines are C5a, IL-8, monocyte chemotactic protein 1alpha (MIP1alpha) or monocyte chemotactic protein 1beta (MIP1beta), monocyte chemoattractant protein 1 (MCP-1), monocyte chemoattractant protein 2 (MCP-2), monocyte chemoattractant protein 3 (MCP-3), platelet activating factor  
 25 (PAFR), N-formyl-methionyl-leucyl-phenylalanine (FMLPR), leukotriene B<sub>4</sub> (LTB<sub>4</sub>R), gastrin releasing peptide (GRP), RANTES, eotaxin, lymphotactin, IP10, I-309, ENA78, GCP-2, NAP-2, MGSA/gro, DC-CK1, Flt3L (ectopic domain), fractalkin, PF-4 etc.

30 Another type of immune modulators are those derived from cell membrane anchored receptor/ligand pairs involved in modulation of a triggered immune response, such as costimulation (for instance lymphocyte surface bound receptors and corresponding cell bound ligands). Illustrative examples are members selected  
 35 from the pairs CD40L/CD40, CD28/B7, CTLA-4/B7 etc. B7 includes variants such as CD80 and CD86 with preference for the former.

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Preferred forms are soluble, contain the extracellular part (ectopic domain) and are devoid of the intracellular and membrane anchored parts.

Particularly preferred immune modulators are capable of potentiating the effects of superantigens in vivo, for instance by counteracting escape of superantigen activated T-cells into anergy. Typical appropriate cell bound receptors/ligands are CD28/B7 including analogues and fragments as defined above. Typical cytokines of this group are IL-2, as being the main downstream effector of CD28/B7 signaling, and the IL-2 like cytokines IL-7 and IL-15. Among T cell surface associated receptor/ligand pairs the member not bound to the T cell to be activated is preferred to be incorporated in a conjugate according to the invention. For CD40L/CD40 and CD28/B7 this means soluble forms of B7 and CD40 with preferences as defined above. The experimental part of this text illustrates the immune modulator variants that at the priority date were found optimal in the invention.

Immune modulators should preferably be of the same species origin as the individual who is intended to be treated. Native immune modulators, such as cytokines and chemokines, often show a high systemic toxicity and a relatively short half live in mammals. The literature is extensive on how to modify immune modulators to an increased stability relative oxidation, a longer in vivo half life, a lower toxicity, an improved refolding when produced by recombinant techniques etc. For instance US 5,229,109 (Grimm et al) describes low toxicity analogues of IL-2 having a reduced affinity to the high affinity IL-2 receptor (IL-2R) by being deficient in binding to the p55 alpha subunit of the receptor. The analogues are primarily prepared by mutating the codon for an amino acid in position 33-46 in IL-2 (for instance Arg38Ala and Phe42Lys or Phe42Ala). The Asp20Lys mutant has 100-500 fold reduced affinity for the p75/beta-chain of the IL-2 receptor without affecting binding to p55 (Collins et al 1988). Other mutations, e.g. Asp20Ser are less severe (Berndt et al 1994). Studies on

murine IL-2 indicates that Asp84 and Asp88 of human IL-2 are also implicated in p75 binding (Zurawski et al 1993). This is supported by modelling of the binding between human IL-2 and its receptor (Bamborough et al 1994). The expected reduction in 5 affinity of these mutations is Asp20>Asn88>Asp84.

Combining the mutations in Arg38 and Phe42 with mutations in position 88 and 20 would result in a still lower affinity for IL-2R. Another potent and at the priority date preferred IL-2 mutation is Thr51Pro that gives an IL-2 analogue with a lowered 10 rate of cell internalization and a prolonged duration of its immune modulating effect (Chang et al 1996).

The numbering of amino acid positions is according to Taniguchi et al 1983.

The publications by Grimm et al; Collins et al 1988; Berndt 15 et al 1994; Zurawski et al 1993; Bamborough et al 1994; Chang et al 1996; and Taniguchi et al 1983 are incorporated by reference.

The use of cytokine and chemokine analogues with a reduced affinity for their normal receptors in conjugates as described 20 above will strengthen their targeting to the preselected target cell. It is conceivable that cytokines and chemokines mutated to show a reduced rate of cell internalization upon binding to their respective cell receptor and incorporated into a conjugate according to formula I will results in a prolonged 25 superantigen activity compared to corresponding conjugates with the native form of the immune modulator.

The term immune modulator (IM) thus encompasses any modified form, for instance any mutated form, that is capable of agonizing or antagonizing the effects of the corresponding 30 native form the immune modulator.

#### B. THE SUPERANTIGEN PART SAG IN FORMULA I

Sag in formula I represents a superantigen as defined for free superantigens and under heading "Background..." above, 35 i.e. wild-type superantigens possibly modified, for instance by mutation,

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- a. to have a decreased ability to bind to MHC class II antigen compared to the corresponding wild type superantigen (see for instance in Abrahmsén et al (W09601650));
- b. to have a decreased seroreactivity in human sera compared to the corresponding wild-type superantigen (see for instance Abrahmsén et al (W09601650) and Antonsson et al PCT/SE97/00537 and Antonsson et al 1997);
- c. to have a decreased immunogenicity in humans compared to the corresponding wild-type superantigen (see for instance Antonsson et al PCT/SE97/00537 and Antonsson et al 1997);
- d. to be a chimera between two or more analogous wild-type superantigens in which one region in one first wild-type superantigen has been replaced with the corresponding region in a second analogous superantigen. The region in question may be a region determining binding to TCRVbeta, e.g. as defined for SEE/SEA and SEA/SEE chimeras (see for instance Antonsson et al PCT/SE97/00537; Antonsson et al 1997; and Lamphaer et al 1996).

Also other modifications/mutations that may be found appropriate are included, for instance to avoid undesired glycosylation when produced in eucaryotic cells.

Typical mutations for SEA/SEE-like superantigens at the priority were (numbering as used by Antonsson et al, 1997 and Antonsson et al PCT/SE97/00537):

- a. decreased MHC class II binding: Asp227Ala (= SEAm9), Phe47Ala and/ or Asp70Arg. The mutant Phe47Ala/Asp227/Ala = SEAm23.
- b. and d. chimeras between SEA and SEE, aimed at reducing seroreactivity in humans, while retaining SADCC capability of the corresponding conjugated superantigen: SEE with the following substitutions Gly20Arg, Thr21Asn, Gly24Ser, Lys27Arg.

The mutants used in the experimental part are SEA(Asp227Ala) = SEAm9, SEA(Phe47Ala/Asp227/Ala) = SEAm23 and

- SEA(Phe47Ala/N102Q/N149D/T218V/Asp227Ala) = SEAm57.

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At the priority filing preferred superantigens were selected among

1. superantigens (Sag) that exhibit two MHC class II binding sites (for instance staphylococcal enterotoxins A and E),
2. superantigens (Sag) that required Zn-ion for binding to MHC class II (for instance SEA, SEE and SEH),
3. Staphylococcal enterotoxins.

A Sag molecule that is to be incorporated into a conjugate according to the invention does not need to be a functional superantigen, the main issue being that the final conjugate is so by exerting either or both of SADCC and SDCC as outlined above.

#### 15 C. Targeting moiety T in formula I.

T can in principle be any structure that is able to bind to a cell surface structure, preferably a disease specific structure. The structure against which T is directed is usually different (a) from the polymorphic TCR chain epitope to which Sag binds, and (b) from the MHC class II epitopes to which Sag binds. The target-seeking moiety may be selected among interleukins (e.g. interleukin-2), hormones, antibodies including antigen binding fragments of antibodies, growth factors etc. See for instance Woodworth 1993 (hereby incorporated by reference).

The targeting moiety may thus be a protein containing 1, 2, 3 or 4 polypeptide chains.

At the priority date, it was preferred that T was an antibody (full length antibody, Fab, F(ab)<sub>2</sub>, Fv, ScFv (single chain antibody), multiple single chain antibodies (ScFv)<sub>n</sub> and any other antigen binding antibody fragment), including any functionally active truncated form of the antibody forms mentioned above. Other variants are monospecific and bispecific. The antibody may in principle be directed towards any disease associated/specific cell surface structure, for instance structures linked to any of the cancer forms given

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above, with particular emphasis for antibody active fragments (such as Fab). Typically the antibody may be directed towards a colon and/or pancreatic specific epitope, for instance the so called C242 epitope (Lindholm et al WO9301303), a lung cancer specific epitope for instance the epitope for the 5T4 antibody (Stern et al WO8907947), a lymphoma specific epitope for instance on CD19, a melanoma specific epitope etc.

The term "antibody" comprises monoclonal as well as polyclonal variants, with preference for monoclonal preparations.

In case the target moiety is a Fab fragment the cysteine residues normally linking the heavy and light Fab chains together preferably have been replaced by an amino acid not permitting disulfide formation, for instance serine. See also Antonsson et al PCT/SE97/00537.

What has been said above also includes that T may be directed towards unique structures on more or less healthy cells that regulate or control the development of a disease.

#### 20 D. The linker B.

The linker B may be selected as previously described (Dohlsten et al WO9201470; Abrahmsén et al WO9601650; and Antonsson et al PCT/SE97/00537), i.e. B shall preferably be hydrophilic and exhibit one or more structure(s) selected among amide, thioether, disulphide etc. The most prominent linkers are those obtained by recombinant techniques, i.e. conjugation takes place at the genomic level resulting in oligopeptide linkers. Typically oligopeptide linkers contain 1-30, such as 1-20, amino acid residues that preferably are selected so that the linker in total is hydrophilic. The linker residues thus preferably are selected among hydrophilic amino acid residues, such as Gln, Ser, Gly, Glu, Pro, His and Arg. Typical oligopeptide linkers comprise the tripeptide GlyGlyPro or the so called Q linker (Wootton et al 1989 hereby incorporated by reference) possibly modified with gly-pro at the amino terminal end.

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# E. ATTACHMENT POINTS FOR T, SAG AND IM

Chemical conjugates will typically contain a mixture of conjugate molecules differing in linking positions. The conjugate substance will contain hetero- as well as homo-conjugates.

For recombinant conjugates (fusion proteins) the obtained conjugate substance will be uniform with respect to the linking position. For each individual subunit (T, Sag, IM) the amino terminal is fused to the carboxy terminal of another subunit or vice versa, preferably via an inserted oligopeptide bridge. The combinations in case the conjugate contains one each of T, IM, Sag will be T-IM-Sag, IM-T-Sag, Sag-IM-T, Sag-T-IM, T-Sag-IM, IM-Sag-T (the occurrence of linker structure of B is not shown). In case one or more of the subunits contains two or more polypeptide chains the number of possibilities increase. For T being an antibody Fab fragment the possibilities will be (the oligopeptide linkers B are not shown):

- |                            |                         |
|----------------------------|-------------------------|
| 1. Sag-Fab(light chain)-IM | 2. Fab(light chain)     |
| 20 Fab(heavy chain)        | Sag-Fab(heavy chain)-IM |
| 3. Sag-Fab(light chain     | 4. Fab(light chain)-IM  |
| Fab(heavy chain)-IM        | Sag-Fab(heavy chain)    |
| 25 5. Sag-Fab(light chain) | 6. IM-Fab(light chain)  |
| IM-Fab(heavy chain)        | Sag-Fab(heavy chain)    |
| 7. Fab(light chain)-Sag    | 8. Fab(light chain)-IM  |
| Fab(heavy chain)-IM        | Fab(heavy chain)-Sag    |

30 In further variants the immune modulator and the superantigen may be fused in sequence at any end of any of the chains in the antibody.

At the priority date recombinant conjugates were preferred, with utmost preference for Fab fragments as targeting moiety and linking of the amino terminal of the free superantigen to the first constant domain of the heavy or light antibody chain

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(CH1) and the immune modulator to the remaining carboxy terminal (valid for formulae I-IV). The analogous combinations at the amino terminal or combination of attachments at the amino and carboxy terminals of the VH and VL domain were at this stage believed to result in active but less efficient conjugates.

F. Active entities not complying with formula I but used according to the combinations a-e above in the inventive method.

Free superantigens (Sag): See under heading "Definition". Typical Sags are given under the headings "Background " and "B. The superantigen part of Sag in formula I".

Unconjugated immune modulators: See under heading "Definition". In principle the same immune modulators as given under the heading "A. The immune modulator IM in formula I" can be used. Cytokines and chemokines are preferred with emphasis for IL-2 and IL-2-like cytokines.

Targeted immune modulators (T,IM-conjugates): These conjugates comply with the general formula



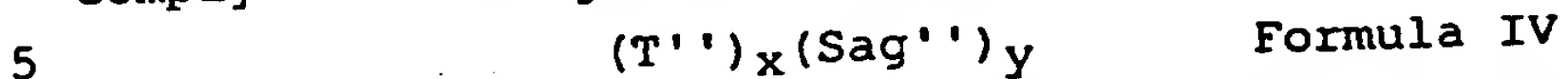
in which T' and IM' are linked together by an organic linker B'. T', IM' and B' are selected among the same groups of compounds/structures as T, IM and B. x and z are defined in the same way as in formula I (y = 0), with preference for one or two IM' per T' and conjugate molecule. The attachment points between T' and IM' are as defined for formula I. See also under heading "E. Attachment points....." in which the formulae 1-6 and comments thereto are applicable also to T,IM conjugates except that Sag is omitted. Conjugates of formula III can be manufactured according to known techniques, i.e. conventional chemical linking or recombinant techniques (fusion proteins), with preference for the latter (Fell et al EP 439095; Rosenblum et al EP 396387). Particularly important T,IM-conjugates comprise an IM'-moiety that has been modified, for instance

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mutated, to a reduced affinity and/or reduced rate of internalization as defined above.

Targeted superantigens (T,Sag-conjugates). These conjugates comply with the general formula

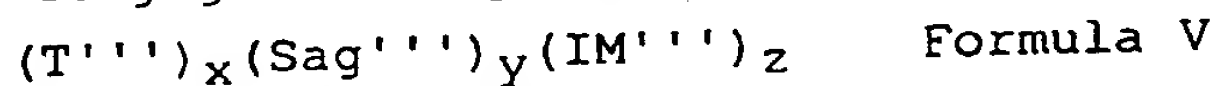


in which T'' and Sag'' are linked together by organic linkers B''. T'', Sag'' and B'' are selected among the same groups of compounds/structures as T, IM and B. x and y are defined in the same way as in formula I (z = 0), with preference for one or  
10 two Sag'' per T'' and conjugate molecule. The attachment points between T'' and Sag'' are as defined for formula I. See also under heading "E. Attachment points....." in which the formulae 1-6 and comments thereto are applicable also to T,Sag conjugates except that IM is omitted from the formula.  
15 Conjugates of formula II can be manufactured according to known techniques, i.e. conventional chemical linking or recombinant techniques (fusion proteins), with preference for the former. See for instance Dohlsten et al WO9201470; Abrahmsén et al WO 9601650, Antonsson et al WO PCT/SE97/00537.

20

Third major aspect of the invention: Conjugates containing a modified immune modulator.

These novel conjugates complies with the formula:



25 where T''' and Sag''' are selected among the same compounds as T and Sag for formula I. IM''' is an immune modulator that has been modified, for instance by mutation, to exhibit a lowered affinity to its cell membrane anchored receptor and/or a lowered rate of internalization via binding to its receptor  
30 (compared to corresponding native forms). IM'' is preferably a cytokine or a chemokine. See further under heading "A. The immune modulator IM in formula I". One important immune modulator for this aspect of the invention is modified IL-2. x, y and z are defined in the same way as in formula I.

35 In a first subaspect of conjugates according to formula V, T''', Sag''' and IM''' are always present (all x, y and z > 0),

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i.e. T,Sag,IM-conjugates.  $x$ ,  $y$  and  $z$  are typically integers 1-3, with preference for 1-2. Typical relations between  $x$ ,  $y$  and  $z$  are:  $x = y = z$ ;  $x = y = 0.5z$ ;  $x = 0.5y = 0.5z$ ; and  $x = 0.5y = z$ .

- 5 In a second subaspect of conjugates according to formula V, the superantigen moiety is absent ( $y = 0$ ), i.e. T,IM-conjugates.  $x$  and  $z$  are typically integers 1-3. Preferred relations between  $x$  and  $z$  are:  $x = z$ ;  $x = 0.5z$ ,  $0.5x = z$ ;  $x = 1/3z$  and  $1/3x = z$ .
- 10 In both subaspects of conjugates according to formula V, the ranges given for integers and their interrelations primarily refer to fusion proteins in which the targeting moiety may be a protein containing 1, 2, 3 or 4 polypeptide chains and in which there are one T in each conjugate molecule. The attachment
- 15 points in fusion proteins of formula V are the same as for corresponding fusion proteins complying with formula I. See also under heading "E. Attachment points....." in which the formula 1-6 and comments thereto are applicable also to T,IM conjugates except that, for the second subaspect, Sag is
- 20 omitted.

#### Manufacture of conjugates defined above.

The manufacture of conjugates may be carried out in principle according to two main routes:

- 25 1. Chemical linking of the individual subunits T, Sag and IM together. Each individual subunit or combination of them may have been produced by recombinant techniques.
2. Recombinant techniques directly providing a conjugate as defined in any of formulae above.

- 30 The factual methods are well recognized for the average skilled worker and comprise a large number of variants.

Chemical linking typically utilizes functional groups (e.g. primary amino groups, carboxy groups, mercapto, carbohydrate groups) that typically are natively present in several

35 positions of superantigens, proteinic immune modulators and

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proteinic targeting moieties. The techniques are well-known in the art.

The main host cell for large scale recombinant production of the inventive conjugates between a superantigen and an immune modulator (fused forms as well as non-conjugated forms) is E. coli. This host provides for in principle two routes: intracellular production and secretion. The latter variant is preferred because it offers purification of correctly folded proteins from the periplasma and from the culture medium. The above does not exclude that it is possible to produce active conjugates also in other host cells, e.g. eukaryotic cells, such as yeast or mammalian cells. Preliminary results have so far indicated that eukaryotic cells, such as mammalian cells, may be preferred for incorporating immune modulators interacting with CD28, for instance B7 and its analogues.

#### THE FOURTH ASPECT OF THE INVENTION: GENE CONSTRUCTS ENCODING THE NOVEL INVENTIVE CONJUGATES.

A fourth aspect of the invention is a recombinant nucleic acid molecule, preferably DNA, such as cDNA, or RNA, encoding a superantigen and an immune modulator as defined above, with preference for IL-2, IL-7, IL-12, IL-15, IL-18, RANTES, ectopic domain of CD80, ectopic domain of CD86, and Flt3L and their analogues as defined above. In this aspect of the invention, the nucleic acid typically should contain regulatory control sequences such as translation regulatory sequences, origin of replication, secretory signal sequences either for one or both of the immune modulator and the superantigen, etc that are compatible with the host cell in which the immune modulator and the superantigen are to be expressed. The region between the part sequences encoding the superantigen and the immune modulator may comprise a sequence encoding a ribosome entry sites such as in bicistronic gene constructs. The latter will allow separate expression of each polypeptide chain comprised within the conjugate. In case of multichain conjugate combinations containing IM, Sag, targeting moiety conjugate and

the proper signal sequences, biscistronic constructs will facilitate folding and assembly to fully active conjugates with IM bound to one of the chains. This will be important for cases in which the targeting moiety is a two chain antibody molecule and at least one of the superantigen (Sag) and the immune modulator is fused to a terminal end of the antibody chain. See above.

#### PHARMACEUTICAL COMPOSITIONS, DOSAGE AND ROUTES OF ADMINISTRATION.

10 A fourth aspect of the instant invention is a pharmaceutical composition containing the inventive combination of superantigen (Sag), targeting moiety (T) and immune modulator (IM). The characteristic feature of this aspect of the invention is that at least one of the superantigen and the  
15 immune modulator is in the form of a conjugate permitting targeting to cells that are to be inactivated as described above.

The compositions contemplated are known in the field, except that now they contain the inventive conjugate combination. In a  
20 particular composition the combination may comprise:

- a. a triple conjugate comprising a superantigen (Sag), a targeting moiety (T) for the target cells and an immune modulator (IM) (T,IM,Sag-conjugate);
- b. two dual conjugates - one between a targeting antibody (T) and a superantigen and one between a targeting antibody (T') an immune modulator (i.e. T,Sag-conjugate + T',IM-conjugate). T and T' may be different or equal as regard to epitope specificity;
- c. on dual conjugate between a superantigen (Sag) and a targeting moiety (T), and an immune modulator (IM) in free form (T,Sag-conjugate + IM);
- d. one dual conjugate between an immune modulator (IM) and a targeting moiety (T), and a superantigen in free form (Sag) (T,IM-conjugate + Sag); or
- 35 e. a superantigen (Sag) and an immune modulator (IM) in form of a dual conjugate (Sag,IM-conjugate);

See further above in the context of the inventive methods. In case the compositions contain two active components (b-d above) the composition may allow for keeping the components apart up to the occasion for administration.

5 The compositions may be in the form of a lyophilized particulate material, a sterile or aseptically produced solution, a tablet, an ampoule etc. Vehicles such as water (preferably buffered to a physiologically acceptable pH value by for instance PBS) or other inert solid or liquid material  
10 may be present. In general terms the compositions are prepared by the conjugate, possibly in combination with an unconjugated active component, being mixed with, dissolved in, bound to, or otherwise combined with one or more water-soluble or water-insoluble aqueous or non-aqueous vehicles, if necessary  
15 together with suitable additives and adjuvants. It is imperative that the vehicles and conditions must not adversely affect the activity of active components as defined in a-e above.

Normally the superantigens (SAG) to be used in the invention  
20 will be sold and administered in predispensed dosages, each one containing an effective amount of SAG that, based on the result now presented, is believed to be within the range of 1pg - 50 mg. The exact dosage will vary from case to case depending on the patient's weight and age and pretiter of antibodies  
25 specific for the SAG used, route of administration, type of disease, target-seeking moiety, superantigen, linkage (-B-), immune modulator etc.

An important factor to account for in determining the dose for a combination to be used in the inventive method is that  
30 superantigens and immune modulators exert optimal dose ranges. A too low dose will result in no or a suboptimal effect and a too high dose will give unacceptable side effects such as toxicity that may be lethal. Thus it has to be emphasized the broad range given above is an attempt to encompass all ranges  
35 possible for all variants of the inventive method. Thus, each specific combination according to the inventive method has a



dose subrange within the range of 0.1pg to 50mg. This does not exclude that future developments and results may lead to dose levels outside this range.

The administration routes will be those commonly contemplated within the field, i.e. a target killing effective amount or therapeutically active amount of a superantigen-immune modulator combination according to the invention is brought into contact with the target cells. For the indications specified above this mostly means parenteral administration, such as injection or infusion (subcutaneously, intravenously, intraarterial, intramuscularly, intraperitoneal) to a mammal, such as a human being. The conjugate combination of the invention may be administered locally or systemically.

By the term "target killing effective amount" is contemplated that the amount is effective in activating and directing T cells to destroy target cells.

The preferred administration routes at the priority date are the same as contemplated for the superantigen conjugates according to Dohlsten et al WO9201470; Abrahmsén et al WO9601650 and Antonsson et al PCT/97/00537. This means 1-5 hours' intravenous infusion (preferably 4 hours) per day combined with a fever-reducing agent (paracetamol). The administration is to be repeated during some days, for instance 5-8 days, with care consideration taken for the risk of boosting antibodies directed towards the conjugate. Optimally, several cycles of therapy with each cycle containing treatment during one or more days followed by a rest period during one or more days, e.g. cycles with treatment and resting during 5 and 2 days, respectively.

The inventive compositions may be administered either as the main therapy or in preferred modes as adjuvant therapy in connection with surgery or with other drugs.

## EXPERIMENTAL PART

Legends to the figures.

- Figure 1. FACS analysis of CHO-CD28 cells stained with CD80-C215Fab, CD80-C215Fab-SEAm57 or C215Fab-SEA followed by incubation with anti-mouse kappa chain mAb labeled with PE. The staining were done at 4°C without any washes.
- 5 Figure 2. FACS analysis of Colo205 cells stained with CD80-C215Fab, CD80-C215Fab-SEAm57 or C215Fab-SEA followed by incubation with anti-mouse kappa chain mAb labeled with PE. The staining were done at 4°C with three washes between each staining step.
- 10 Figure 3. Proliferation. T cells were incubated with Colo205 cells and 4uM C242Fab-SEA and varying amounts of CD80-C215Fab for 4 days after which the incorporated  $^3\text{H}$  - thymidine was counted. The activity obtained without any CD80-C215Fab was 20039cpm +/- 1750.
- 15 Figure 4. IL-2 production. T cells were incubated with Colo205 cells and 4uM C242Fab-SEA and varying amounts of CD80-C215Fab for 4 days after which the supernatant was harvested and the amount IL-2 was determined. The amount IL-2 obtained without any CD80-C215Fab was 2849 pg/ml .
- 20 Figure 5. Proliferation. T cells were incubated with Colo205 cells and varying amounts of CD80-C215Fab-SEAm57 or C215Fab-SEAm23 for 4 days after which the incorporated  $^3\text{H}$  -thymidine was counted.
- Figure 6. IL-2 production. T cells were incubated with Colo205  
25 cells and varying amounts of CD80-C215Fab-SEAm57 or C215Fab-SEAm23 for 4 days after which the supernatants were harvested and the IL-2 contend determined.
- Figure 7. Proliferative capacity of human blood T cells  
30 incubated for 7 days with the indicated proteins and irradiated, transfected CHO cells (for presentation of SEA) .
- Figure 8. Simultaneous administration of targeted SEA and IL2  
35 leads to enhanced T cell activation *in vivo*. Cytotoxicity against SEA-coated MHC class II<sup>+</sup> Raji cells of splénocytes from mice treated with 1 or 3 injections of C215FabSEA (FS), C215Fab-Q-hIL2 (FI), combination of the

two (FS+FI) or C215FabSEA-Q-hIL2 (FSI). Effector:target cell ratio was 100:1, and cytotoxicity was measured in a standard 4hr  $^{51}\text{Cr}$  release assay

5 Figure 9. Improved therapy of day 5 B16-C215 tumors in C57Bl/6 mice with three injections of C215FabSEA + C215Fab-Q-hIL2 (days 5,6 and 7 after tumor inoculation). Equimolar amounts of FabSEA and Fab-Q-hIL2 were used.

10 Figure 10. Increased tumor infiltration of  $\text{CD25}^+$  T cells following Fab-SEA + Fab-Q-IL2 treatment. CD4, CD8 and CD25-positive cells infiltrating the lung of mice carrying established B16-GA733 lung tumors were estimated by immunohistochemistry. In the case of C215Fab-SEA-Q-hIL2 a maximum of 3 injections was given, due to toxicity after the 4th injection.

15 Figure 11. Therapy of day 3 B16-C215 tumors in C57 Bl/6 mice following treatment with 8 injections of C215FabSEA (= FS) C215FabSEA<sub>D227A</sub>(= FSm9), or C215FabSEA<sub>D227A</sub>-Q-hIL2 (= FSm9-IL2). Treatment given daily for 8 consecutive days. On day 21 animals were sacrificed, and lung metastases counted.

20 Figure 12. Therapy of day 3 B16-C215 tumors in Vb3 TCR transgenic mice following treatment with 8 injections of C215FabSEA<sub>D227A</sub>-Q-hIL2<sub>F42A</sub>(= FSm9-IL2(F42A)), C215FabSEA<sub>D227A</sub>-Q-hIL2(= FSm9-IL2), or C215FabSEA<sub>D227A</sub>(= FSm9-IL2),. Treatment was given daily for 8 consecutive days. On day 25 21 animals were sacrificed, and lung metastases counted.

25 Figure 13. Therapy of day 3 B16-C215 tumors in Vb3 TCR transgenic mice following treatment with 8 injections of C215FabSEA<sub>D227A</sub>-Q-hIL2<sub>F42A</sub>(= FSm9-IL2(F42A)), C215FabSEA<sub>D227A</sub>-Q-hIL2<sub>F42K</sub>(= FSm9-IL2(F42K), C215FabSEA<sub>D227A</sub>-Q-hIL2<sub>F42A/D20S</sub>(= FSm9-IL2(F42A/D20S)), or C215FabSEA<sub>D227A</sub>(= FSm9),. Treatment was given daily for 8 consecutive days. On day 30 21 animals were sacrificed, and lung metastases counted.

35 EXAMPLE 1. BIOLOGICAL ACTIVITY OF CD80-C215FAB FUSION PROTEINS FOR USE IN COSTIMULATION OF TUMOR THERAPY WITH SAG TARGETED FAB.

**Summary:** CD80-C215Fab and CD80-C215Fab-SEAm57 fusion proteins have been constructed to contain the extracellular domain of human CD80. The fusion proteins were produced in mammalian cells, and tested for binding to CD28 using CHO cell  
 5 transfectants and C215 antigen using Colo205 cells. Both fusion proteins bound to CD28 and C215 antigen, the later binding being 100-fold reduced compared to C215Fab-SEA. Since CD80 is linked to the N-terminal part of the L-chain it is possible that the CD80 moiety interferes with the C215Fab  
 10 binding. Both fusion proteins costimulate SAG activated human T cells showing that the soluble CD80 retains its biological function.

#### MATERIAL AND METHODS

15 **Recombinant DNA techniques and enzymes:** Plasmid DNA preparations and other operations were performed essentially according to Sambrook et al. (Sambrook et al 1989). E. coli HB101 (Boyer et al 1969) was used as the host strain. Restriction endonucleases and the Klenow fragment of DNA  
 20 polymerase I were obtained from Boehringer Mannheim or New England Biolabs, and used according to the suppliers recommendations. Taq-polymerase was obtained from Perkin Elmer. cDNA was made from the total RNA using the GeneAmp RNA PCR kit (Perkin-Elmer). Oligonucleotides were synthesized on a Gene  
 25 Assembler (Pharmacia Biotech AB) or an ABI 392 DNA/RNA synthesizer (Applied Biosystems), and purified by reversed phase chromatography on the FPLC system (Pharmacia Biotech). Sequencing was done according to the dideoxy chain-termination principle (Sanger et al 1977) using Applied Biosystems Taq  
 30 DyeDeoxy Termination Cycle Sequencing Kit and the products separated and detected on a DNA sequencer ABI 373A (Applied Biosystems). Bacteria harboring different plasmids were selected on plates containing 2 X YT and 15 g agar base per liter, supplemented with 70 mg/L kanamycin, or 100 mg/L  
 35 ampicillin. The liquid broth was 2 X YT (per liter: 10 g yeast extract (Difco), 16 g tryptone (Difco) and 5 g NaCl).

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Table I

	LAKQ5	ATA TAA GCT TCC ACC ATG GGC CAC ACA CGG AGG (SEQ ID NO 1)
5	LAKQ7	ACG CAG ATC TTT AGT TAT CAG GAA AAT GCT CTT GC (SEQ ID NO 2)
	LAKQ30	TCA AAG CTT CTC GAG CGC GCT GTT ATC AGG AAA ATG CTC (SEQ ID NO 3)
	LAKQ37	CGC GCG TCA GGC TAA CGA ACT GCC AGG CGC CCC GTC ACA GAG ACG A (SEQ ID NO 4)
10	LAKQ38	AGC TTC GTC TCA CGC GCG TTC TTC CTG TGA CGG GGC GCC TGG CAG TTC GTT AGC CTG ACG (SEQ ID NO 5)
	LAKQ88	TGG TAC ACC ACA GAA GAC AGC TTG TAT GTA TG (SEQ ID NO 1)
15	LAKQ89	CAT ACA TAC AAG CTG TCT TCT GTG GTG TAC CA (SEQ ID NO 6)
	LAKQ90	CGA ATA AGA AAG ACG TCA CTG TTC AGG AGT TGG (SEQ ID NO 7)
20	LAKQ91	CCA ACT CCT GAA CAG TGA CGT CTT TCT TAT TCG (SEQ ID NO 8)
	LAKQ92	GAG ATA ATA AAG TTA TTA ACT CAG AAA ACA TG (SEQ ID NO 9)
	LAKQ93	CAT GTT TTC TGA GTT AAT AAC TTT ATT ATC TC (SEQ ID NO 10)
25	LAKQ108	CGC GGA TCC GCG CGG CAC CAG GCC GCT GTT ATC CGG AAA ATG CTC TTG C (SEQ ID NO 11)
	LAKQ117	CCG GAT AAC AGC GCG CGT CAG CTA ACG AAC TCC AGG CGC CCC GTC ACA GGA AGAA CGC CCG CAG GTC CAA CTG CA (SEQ ID NO 12)
30	LAKQ118	GTT GGA CCT GCG GGC GTT CTT CCT GTG ACG GGG CGC CTG GCA GTT CGT TAG CCT GAC GCG CGC TGT TAT (SEQ ID NO 13)

35 Plasmid constructions

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The genes encoding a Fab fragment containing the variable domains of the murine antibody C215 were assembled as described previously (Dohlsten et al 1994). Cloning and mutagenesis of the staphylococcal enterotoxin A (SEA) gene yielding the 5 replacements F47A and D227A has been described previously (Abrahmsén et al 1995). Three other mutations were introduced in the SEA gene using the primers LAKQ88-93 (all oligonucleotides used are compiled in Table I) to obtain SEA mutant 57. LAKQ5 and LAKQ7 were used in RT-PCR to introduce a 10 Kozak box upstream, and to clone the gene encoding signal peptide and the extracellular part of human CD80 from human spleen total RNA. The nucleotide sequence was found to correspond to the gene bank sequence of CD80 (Accession number M27533). Two variants of the CD80 gene were made, having 15 different cloning sites at the 3'-end: in separate PCRs the primers LAKQ30 and LAKQ108 were used to obtain a BssHII or a MroI site, respectively. A gene fusion encoding a CD80 fused before the kappa chain by a Q-linker (Wooton et al 1989), was constructed by inserting the DNA linker LAKQ37/38 BssHII- 20 Esp3I, between the relevant CD80 gene and a DsaI site directly preceding the kappa gene. The plasmid pKGE987 was obtained by inserting the gene fusion encoding CD80-(Q-linker)-kappa, preceded by the CD80 signal peptide into a vector, which in addition to a CMV promoter and a poly A tail contains a 25 neomycin gene to be used for selection of transformants. The last version of the CD80 gene was used to construct a gene fusion where it precedes the Fd-SEA mutant 57 gene fusion: a DNA fragment (LAKQ117/118) encoding a Q-linker was inserted between a MroI site in the CD80 gene and a PstI site at codon 4 30 and 5 in the C215 VH gene. This gene fusion was inserted in a second CMV promoter vector to yield the plasmid pMB189, thus encoding the CD80 signal peptide and extracellular portion followed by Fd and SEA mutant 57, connected by the three residue spacer GGP. In the plasmid pKGE961 the Fd gene has been 35 inserted following a signal sequence (derived from another murine VH gene). The plasmid pMB156 encodes the native kappa

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chain, preceded by its native signal peptide, and contains the neomycin gene.

#### Production

5 Hamster embryonic kidney 293 cells were transfected with either pKGE961 and pKGE987, or with pMB156 and pMB189, to obtain cell lines producing CD80-C215Fab, and CD80-C215Fab-SEAm57, respectively. To obtain stable cell lines the selection medium was DMEM without phenol red (Pharmacia no MS 0127) supplemented  
10 with L-glutamine (GIBCO BRL no 25030-24), 10% bovine calf serum and Geneticin 1 mg/ml. The production medium was DMEM without phenol red supplemented with L-glutamin and 0,1% HSA (Pharmacia & Upjohn AB, Sweden). Fusion proteins were purified from the filtrated (Sartobran 0.65- 0.4 um) culture media by affinity  
15 chromatography on protein G Sepharose FF (Pharmacia Biotech AB), followed by anti-CD80 affinity purification (immobilized anti-human CD80 antibody; Camfolio L307.4) or ion-exchange chromatography on SP Sepharose FF (Pharmacia Biotech).

20 Reagents. RPMII 1640 medium (Gibco, Middlesex, UK) supplemented with 2 mM L-glutamin (Gibco, Middlesex, UK), 0.01 M HEPES (Biological Industries, Israel), 1 mM NaHCO<sub>3</sub> (Biochrom KG, Berlin, Germany), 0.1 mg/ml gentamicin sulfate (Biological Industries, Kibbutz Beit Haemek, Israel), 1 mM sodium pyruvate  
25 (JRH Biosciences Industries, USA) and 10% heat inactivated fetal bovine serum (Gibco Middlesex, UK) was used as complete medium for all cell cultures.

**Antibodies.** mAbs directed to human CD57 (HNK1) and CD56 (HB55) were obtained from the mAb producing hybridoma cells (American  
30 Type Culture Collection, Rockville, MD). Anti-mouse kappa chain mAb labelled with PE was obtained from Becton Dickinson (San Jose, CA)

**Cells.** Chinese hamster ovary (CHO) K1 cells were transfected with human cDNA encoding the CD28 gene at Pharmacia and Upjohn,  
35 Stockholm, Sweden. The transfectants were routinely analyzed for CD28 expression and maintained by FACS sorting at similar

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antigen expression levels. The human colon carcinoma cell line Colo205 was obtained from ATCC. All cell lines were free of mycoplasma.

**T lymphocyte proliferation assay.** T cells were obtained from 5 human peripheral blood mononuclear cells (PBM) as previously described (Lando et al 1996) by negative selection panning with CD57, HLA-DR4, CD14 and CD56 mAbs. All tests on T cells were performed with  $0.1 \times 10^6$  cells/well in 200  $\mu$ l volumes, using flat-bottomed 96-well plates (Nunc, Roskilde, Denmark). DNA-  
10 synthesis was studied after exposure of cultures to [ $^3$ H]-thymidine [ $^3$ H]TdR (0.5mCi/well) as described earlier (10).

**Analysis by flow cytometry.** Flow cytometric analysis and sorting were performed according to standard setting on a FACStar<sup>Plus</sup> flow cytometer (Becton Dickinson, Mountain View,  
15 CA). Due to the low affinity of CD80 to CD28 staining of CHO-CD28 cells with CD80-C215Fab fusion proteins were done omitting washes of the cells.

**Cytokine assay.** The production of IL-2 was analyzed using a IL-2 ELISA kit ( huIL-2 DuoSet, Genzyme).

20

## Results.

**Description of the CD80-Fab fusion proteins.** The Fab moiety is of murine IgG1/k isotype although it contains the variable domains of the IgG2A/k monoclonal antibody C215 (Dohlsten et al  
25 1995). The tripeptide sequence GGP follows the inter-chain disulphide forming cysteine in the CH1 domain. In the CD80-C215Fab-SEAm57 triple fusion protein, this functions as a spacer between Fd and a mutant of staphylococcal enterotoxin A (SEA; Betley et al 1988), having five substitutions. The  
30 replacements F47A and D227A were introduced to diminish affinity for MHC class II (Abrahmsén et al 1995), and the replacements N102Q, N149D and T218V were introduced to avoid fortuitous glycosylation when produced in eukaryotic cells. These latter replacements were selected with the aid of the X-  
35 ray structure (Sundström et al 1996). The final penta mutant was designated SEA mutant 57. Both fusion proteins contain the

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extracellular domain of human CD80 (defined to end FPDN). The native CD80 signal peptide was used and the mature protein found to start VIH<sub>V</sub>, as determined by amino acid sequencing of purified CD80-C215Fab. A spacer of 18 amino acids connects CD80 with the kappa chain in CD80-C215Fab, or the Fd portion of the Fab fragment in the CD80-C215Fab-SEAm57 triple fusion protein. The spacers resemble a Q-linker (Wooton et al 1996) and have the sequences SARQANELPGAPSQEERA (SEQ ID NO 14) and SARQANELPGAPSQEERP (SEQ ID NO 15), respectively.

10

**Facs analysis:** Binding of CD80-C215Fab fusion proteins to CD28 positive cells and to C215 positive cells.

**CD28 positive cells:** CHO-CD28 cells were stained with CD80-C215Fab, CD80-C215Fab-SEAm57 or C215Fab-SEA followed by incubation with anti-mouse kappa chain mAb labeled with PE. The staining were done at 4°C without any washes.

Both the CD80-C215Fab and the triple fusion protein bound to CD28 expressed on the CHO cells in a dose dependent manner. No staining was, as expected, seen with the control fusion protein C215Fab-SEA.

**C215 positive cells.** The binding of the fusion proteins against the C215 antigen was evaluated against Colo205 cells. Colo205 cells were stained with CD80-C215Fab, CD80-C215Fab-SEAm57 or C215Fab-SEA followed by incubation with anti-mouse kappa chain mAb labeled with PE. The staining were done at 4°C with three washes between each staining step.

**Results (figures 1-2):** Both CD80-C215Fab and CD80-C215Fab-SEAm57 bound to the C215 antigen positive Colo205 cells in a dose dependent manner. The binding was 50-100 fold lower than that of C215Fab-SEA. This indicates that the introduction of CD80 in the N-terminal part of the fusion protein might interfere with the binding of the C215Fab part to the C215 antigen.

**35 Dual fusions. Costimulation of superantigen activated T cells.**

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To determine the biological activity of the fusion proteins they were tested for costimulation of superantigen activated T cells.

**Proliferation:** T cells were incubated with Colo205 cells and 4uM C242Fab-SEA and varying amounts of CD80-C215Fab for 4 days after which proliferation measured as incorporated  $^3\text{H}$  - thymidine was counted.

**IL-2 production:** T cells were incubated with Colo205 cells and 4uM C242Fab-SEA and varying amounts of CD80-C215Fab for 4 days after which the supernatant was harvested and the amount IL-2 was determined.

**Results (figures 3-4):** CD80-C215Fab costimulated the C242Fab-SEA induced activation of the T cells in a dose dependent manner both seen as proliferation and IL-2 production.

15

**Triple Fusions.** Costimulation of superantigen activated T cells.

To test the biological activity of the triple fusion protein, purified T cells were incubated with C215Fab-SEAm23 (m23 being the same SEA mutant affecting MHC class II binding that was used in the triple fusion protein, i.e. Phe47Ala/Asp227Ala) or CD80-C215Fab-SEAm57 presented on Colo205 cells. Proliferation: The incorporated  $^3\text{H}$  -thymidine was counted after 4 days. IL-2 production: The supernatants were harvested and the IL-2 content determined after 4 days.

**Results (figures 5-6):** The triple fusion protein induced T cell activation and IL-2 production when presented on Colo205 cells. No such activity was seen with the C215Fab-SEAm23 indicating the importance of costimulation by CD80 for activation. Due to the lower binding affinity of the triple fusion protein (50-100x lower than that of C215Fab-SEA, see FACS data), the actual amount of C215Fab-SEAm23 bound to cells is likely to be substantially higher than that of the triple fusion protein.

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**Example 2. Targeted IL-2 potentiates and prolongs the effects of FabSEA on T cell activation and in tumor therapy.**

**Methods and Materials:**

5 Construction of IL2 expression plasmids. The IL2 cDNA was cloned by RT-PCR using mRNA isolated from human peripheral blood mononuclear cells (PBM) which had been stimulated with the superantigen SEA for 24 hours. mRNA was isolated from  $5 \times 10^6$  cells using a mRNA Direct kit from Dynal, Oslo according to the  
10 manufacturer's instructions. mRNA annealed to oligo(dT)<sub>26</sub> - coated magnetic beads was eluted by heating to 95°C. Subsequently a PCR product was obtained by RT-PCR, taking advantage of the RT and DNA polymerase activities of Taq polymerase. 1/10 of the eluted mRNA was mixed with PCR primers  
15 IL2-1 and IL2-2 and a standard PCR reaction performed (30 rounds). The PCR product was subjected to agarose gel electrophoresis, the band excised from the gel and purified using the Prep-a-gene kit (Bio-Rad) kit. Following digestion with EcoRI and BamHI the fragment was cloned into EcoRI/BamHI-  
20 digested pBluescript KS II. The insert was sequenced and confirmed to be identical to the previously reported IL2 cDNA (Taniguchi et al 1983). However, as a result of the PCR reaction a DNA segment encoding the Arg-Gln-Ala-Asn-Glu-Leu-Pro-Gly-Ala-Pro-Ser-Gln-Glu-Glu-Arg "Q-linker" (Wootton et al 1989) had  
25 been added 5' to the segment encoding mature human IL-2. Q-hIL2 was cloned into a plasmid from a house collection (cut with RsrII-XbaI) as a RsrII-NheI fragment. The resulting plasmid, pMS306, directs the secretion of C215FabSEA-Q-hIL2 to the periplasma of E.coli.

30

**Primers:**

**IL2-1:**

5'-GCG GAT CCC GGT CCG CGT CAG GCT AAC GAA CTG CCA  
GGA GCT CCG TCT CAG GAA GAG CGT GCA CCT AC TTC

35 AAG TTC TAC AAA G-3' (SEQ ID NO 16)

**IL2-2:**



5'-CCG AAT TCG CTA GCT TAT CAA GTT AGT GTT GAG ATG  
AT-3' (SEQ ID NO 17)

Expression of the fusion proteins in fermenter. Fusion  
5 proteins were expressed in the *E. coli* K-12 strain UL 635  
(xyl-7, ara-14, T4<sup>R</sup>, deltaompT) using a plasmid with a  
kanamycin resistance gene and lacUV5-promoter. Bacteria from  
frozen stock were incubated at 25°C for approximately 21 h in  
shaker flasks containing (g/l) (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, 2.5; KH<sub>2</sub>PO<sub>4</sub>, 4.45;  
10 K<sub>2</sub>HPO<sub>4</sub>, 11.85; sodium citrate, 0.5; MgSO<sub>4</sub>•7 H<sub>2</sub>O, 1; glucose  
monohydrate, 11, 0.11 mM kanamycin and 1 ml/l trace element  
solution (Forsberg et al., 1989), however without Na<sub>2</sub>MoO<sub>4</sub>•2  
H<sub>2</sub>O. The cells were grown to an OD<sub>600</sub> of 1-2 and 450 ml  
culture medium was used to inoculate a fermenter (Chemap,  
15 Switzerland) to a final volume of 5 l. The fermenter medium  
contained (g/l) (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>, 2.5; KH<sub>2</sub>PO<sub>4</sub>, 9; K<sub>2</sub>HPO<sub>4</sub>, 6; sodium  
citrate, 0.5; glucose monohydrate, 22; MgSO<sub>4</sub>•7 H<sub>2</sub>O, 1; 0.11  
mM kanamycin; 1 ml adecanol (Asahi Denka Kogyo K.K, Japan)  
and 1 ml/l trace element solution. The pH was kept at 7.0 by  
20 titration with 25 % ammonia, the temperature was 25°C and  
aeration with atmospheric air 5 l/min. The partial pressure  
of dissolved O<sub>2</sub> was controlled to 30 % by increasing  
agitation from 300 to 1000 rpm during batch phase and  
regulating the feed of 60 % (w/v) glucose during fed batch  
25 phase. Product formation was induced at an OD<sub>600</sub> of 50 by  
adding 0.1 mM isopropyl beta-D-thiogalactopyranoside, IPTG.  
After fermentation, the cells were removed by centrifugation  
at 8000xg for 40 min at 4°C. The clarified medium was either  
analysed and purified directly or stored at -20°C.

30

Purification of fusion proteins. DNA present in the clarified  
medium was removed using precipitation with 0.19 %  
polyethylenimine and 0.2 M NaCl during 30 min (Atkinson and  
Jack, 1973). After centrifugation as above, the supernatant  
35 was collected and the NaCl concentration adjusted to 0.5 M.  
This medium was applied to a Protein G Sepharose column

(Pharmacia Biotech AB, Uppsala, Sweden) equilibrated with 10 mM sodium phosphate, 150 mM NaCl, pH 7.4 containing 0.05 % Tween 80, PBST. The column was then washed with 5 column volumes PBST and bound protein was eluted with 0.1 M acetic acid, 0.02 % Tween 80 pH 3.2. The pH of the sample was adjusted to 5.0 using 1 M Tris-HCl, pH 8.0, and applied to an SP Sepharose HP column (Pharmacia Biotech) equilibrated with 50 mM ammonium acetate, 0.02 % Tween 80. The column was then washed with 2 column volumes equilibration buffer and the fusion protein eluted using a linear gradient from 50 to 500 mM ammonium acetate over 10 column volumes. For the C215Fab-IL2 fusion proteins, a pH of 6.0 was utilised while for the C215Fab-SEA-IL2 triple fusion proteins, the pH was 5.7 during the separation. The fusion proteins were filtered through a 0.22um filter and stored at -70°C. If more dilute, the eluate is concentrated to a final concentration of 0.5 - 1 mg/ml using Centricon 30 (Amicon) according to the manufacturer's instructions

20 Cytotoxicity assays. MHC class II dependent and independent cytotoxicity assays were performed as previously described (Dohlsten et al., 1990). Briefly for MHC class II dependent assays <sup>51</sup>Cr-labelled Raji cells (2500 cells per well in a final volume of 200 ul) were mixed with an SEA-dependent effector cell line generated by incubation of human PBM in the presence of low levels of recombinant hIL-2. Effector:Target cell ratio was 30:1. For MHC classII-independent assays <sup>51</sup>Cr-labelled C215<sup>+</sup> colo205 cells (2500) were incubated with SEA-dependent effector cells at an E:T ratio of 45:1. <sup>51</sup>Cr released into the medium was determined after 4 hours of incubation by scintillation counting.

In vitro co-stimulation assay on purified human T cells. Naive human T cells were purified essentially as described by Lando et al. (1993). Briefly, naive human T cells were purified from human blood PBM by Ficoll gradient centrifugation, followed by

separation over gelatine columns, and lastly negative selection by panning in petri dishes containing HNK1 and HLA-DR mAbs. Proliferation experiments using naive human T cells was performed essentially as described by Lando et al. (1996).

- 5 Briefly, naive T cells (100.000 cells per well) were combined with irradiated CHO transfectants (10.000 cells per well) in a total volume of 200 ul RPMI-1640 with supplements (Lando et al 1993). For experiments with IL-2 containing fusion proteins, cells were incubated for 7 days in the presence of 1 nM of  
10 the indicated substances. On the final day of the experiment the cells were pulsed with <sup>3</sup>H-Thymidine to measure incorporation into DNA of dividing cells.

- Therapy of B16-C215 tumors. Therapy was performed essentially  
15 as described previously (Dohlsten et al 1994; Hansson et al 1997). On day 0 C57Bl/6 mice were injected i.v. into the tail vein with 75000-150000 syngeneic B16-F10 melanoma cells. These B16 cells were expressing the human GA-733 antigen recognized by the C215 mAb. On day 1,3 or 5 therapy with C215Fab proteins  
20 were initiated. On day 21 the experiment was terminated, at which time the lungs were removed and disseminated lung tumors counted.

- Immunohistochemistry was performed on lungs of animals carrying  
25 Day 18 B16-C215 tumors essentially as described previously (Dohlsten et al 1995). Samples were taken out 4 hours after the final injection. Stained area was determined manually.

- Immunopharmacology was performed essentially as described  
30 (Rosendahl et al 1996). Spleens from C57 Bl/6 mice having received 1 or 3 injections, once daily, were removed 48 hours after the final injection and SEA-dependent cytotoxicity determined, using Raji cells as targets in a standard <sup>51</sup>Cr release assay as described above. E:T ratio was 100:1.

35

## Results and Discussion:

Production and purification of IL2-containing fusion proteins. An *E. coli* expression vector encoding a C215FabSEA-Q-hIL2 triple fusion protein was constructed. This vector encodes the two subunits of the triple fusion protein on a bi-cistronic mRNA transcribed from the *LacUV5* promoter. Each of the two subunits are preceded by a signal peptide directing export to the periplasmic space of *E. coli*. The first subunit is VH of the C215Fab followed by a Gly-Gly-Pro linker (VH-CH1-Gly-Gly-Pro-SEA). The other subunit is VK of C215Fab followed by CK of the C242Fab, which is linked to human IL2 by a Gly-Pro-Q-linker (Vk-Ck-Gly-Pro-Q-hIL2). The Q-linker sequence, Arg-Gln-Ala-Asn-Glu-Leu-Pro-Gly-Ala-Pro-Ser-Gln-Glu-Glu-Arg is a slightly modified version of a natural linker found in the OmpR *E. coli* protein (Wootton et al 1989). See materials and methods for more complete information, and appendix 1 for protein sequence of the two subunits of the triple fusion protein. Also a C215Fab-Q-hIL2 fusion protein was produced. It is identical to C215FabSEA-Q-hIL2 except that the Gly-Gly-Pro-SEA moiety of the protein has been removed. The corresponding DNA sequence in the expression vector is deleted accordingly. Mutated derivatives of C215FabSEA-Q-hIL2 were generated by PCR-mediated site-directed mutagenesis by standard methods to produce a number of proteins such as C215FabSEAD227A-Q-hIL2 and C215FabSEAD227A-Q-hIL2F42A. In later variants of the triple fusion protein the intersubunit cystine is replaced by two serine residues. This alteration does not affect the biological activity.

Plasmids encoding IL2-containing proteins were transformed into the *E. coli* production strain UL635, and fermentation subsequently performed. Fusion proteins were purified from the culture medium using protein G affinity chromatography. Degraded variants of the fusion proteins were removed using ion exchange chromatography. The products obtained were at least 90% full-length fusion protein, as determined by SDS-PAGE (material and methods). Typically, 5-20 mg of biologically active product was purified from a 5 L fermentation.

Functional characterization of IL2-containing Fab fusion proteins. The ability of IL2-containing fusion proteins such as C215FabSEA-Q-hIL2 and C215Fab-Q-hIL2 fusion proteins to induce proliferation of the IL-2 dependent murine cell line CTL-2 was essentially similar to that of recombinant human IL2 on a molar basis (data not shown). Moreover, antigen-binding and SEA activity of C215FabSEA-Q-hIL2 and C215FabSEA were found to be indistinguishable in a number of assays, suggesting that there were no adverse effects of introducing IL2 into the molecule. These assays included ability to induce MHC class II-independent killing of the C215<sup>+</sup> human colon cancer cell line colo205 by an SEA-reactive T cell effector cell line in a 4 hour <sup>51</sup>Cr-release assay. Also MHC class II-dependent killing of MHC class II<sup>+</sup> Raji (rat lymphoma) cells by SEA-reactive effector T cells proceed with similar efficiencies (data not shown). More direct evidence for uncompromised C215 antigen and MHC class II binding was obtained by FACS analysis. The dose dependence of C215FabSEA and C215FabSEA-Q-hIL2 binding to Raji cells was found to be similar on a molar basis (data not shown). Also dose-dependent binding of C215FabSEA-Q-hIL2 and C215Fab-Q-hIL2 to colo205 cells was found to be similar to that observed for C215FabSEA (data not shown), indicating that antigen-binding was uncompromised in the IL2-containing fusion proteins.

IL2-dependent proliferation induced by FabSEA. Resting human T cells require both a signal 1 and a signal 2 to trigger optimal T cell proliferation and activation (Schwartz, 1990). Superantigens can deliver signal 1, if presented on a cell. IL-2 being the major downstream effector of B7/CD28 signalling is expected to give signal 2.

Here we show using resting T cells purified from human blood that a C215FabSEA-Q-hIL2 triple fusion protein or C215FabSEA in combination with C215Fab-Q-hIL2 or recombinant human IL-2 does indeed induce T cell proliferation in vitro (figure 7)

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e. the superantigen (SAG) and the immune modulator is used in form of a dual conjugate between a superantigen (Sag) and an immune modulator (IM) (Sag,IM-conjugate);

The superantigen and the immune modulator may be targeted to the same type of cells, for instance to identical or crossreacting structures/epitopes or to different type of cells within the same tissue. Targeting may be for normal cells or diseased cells associated with one and the same tissue. Either or both of the superantigen and the immune modulator may be targeted with one or several antibodies.

The diseases to be treated by the method of the invention.

The diseases to be treated are in principle the same as those previously suggested for superantigens. See for instance under headings "Background...." above. Illustrative examples are cancers, autoimmune diseases, parasitic infestations, viral infections and other diseases associated with cells that on their surface express MHC class II antigens and/or other structures that are specific for respective disease and bind to the target-seeking moiety incorporated in the superantigen in accordance with the inventive concept (formula I). Also bacterial infections may be combated by the use of the invention.

Important cancer forms in the context of the invention are: melanomas, carcinomas, hematopoietic neoplasias and fibrosarcomas and includes specific forms such as squamous cell carcinoma, breast cancers, head and neck carcinomas, thyroid carcinomas, soft tissue carcinomas, bone sarcomas, testicular cancer, prostatic cancer, ovarian cancers, bladder cancers, skin cancers, brain cancers, angiosarcomas, hemangiosarcomas, mast cell tumors, primary hepatic cancers, lung cancers, cervix cancers, renal cell carcinomas, leukemias and lymphomas. Included are any type of malignant or benign tumors as well as multi-drug resistant cancers, metastatic cancers, various forms of chemically or virally (herpes, SV40, HIV etc) induced cancers.

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cytotoxic activity against SEA-coated Raji cells determined in a standard 4 hr  $^{51}\text{Cr}$  release assay.

Both C215FabSEA-Q-hIL2 and C215FabSEA/C215Fab-Q-hIL2 induced not only enhanced but also sustained T cell activation. Levels of serum cytokines such as IFN $\gamma$ , which dips drastically after the fourth injection of C215FabSEA stays at a very high level even after the fourth injection of C215FabSEA-Q-hIL2 (data not shown). In general, IFN $\gamma$  and TNF $\alpha$  levels were much higher (up to 10x) higher than in the case of C215FabSEA.

10

Improved therapy of established B16-C215 tumors with C215FabSEA and C215Fab-Q-hIL2 combination treatment. The effects of IL2-potentialization of FabSag tumor therapy was investigated in the murine B16 melanoma model (Fig. 9). In the shown example 8-12 week old C57 Bl/6 female mice were inoculated on day 0 with 150,000 B16 cells transfected with the human tumor antigen GA-733, which the C215 mAb is directed against (B16-C215 in the following). The indicated substances were injected on days 5, 6 and 7. Each datapoint corresponds to 7 animals. On day 21 the 20 animals were sacrificed, and the number of melanin-pigmented B16 tumors colonizing the lung counted. Combination of C215FabSEA and C215Fab-Q-hIL2 in several experiments were shown to induce better therapy than C215FabSEA as compared to a non-treated control (figure 9). In the indicated experiment, 25 C215FabSEA/C215Fab-Q-hIL2 combination treatment gave better therapeutic effect than the C215FabSEA-Q-hIL2 triple fusion protein.

Subsequent immunohistochemistry studies revealed that C215FabSEA alone or combination of C215FabSEA and C215Fab-Q-hIL2 gave rise to similar numbers of B16-C215 tumor-infiltrating CD4 and CD8 T cells. Interestingly, however, the number of CD25 (IL2Ra) positive cells - a good marker for T cell activation - dramatically increased between the 3<sup>rd</sup> and 4<sup>th</sup> injection of C215FabSEA/C215Fab-Q-hIL2 (figure 10). In contrast, it decreased in the case of C215FabSEA indicating 35 beginning anergy. The quality of infiltrating T cells thus

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(Sag)<sub>y</sub>(IM)<sub>z</sub> Formula II

This type of conjugates are primarily adapted to the treatment of diseases associated with cells expressing MHC class II antigens, in particular class II expressing cancers, such as  
 5 cancers of the hematopoietic system, and certain autoimmune diseases, viral infections and parasitic infestations, but also with diseases associated with cell membrane anchored receptors for the immune modulator, for instance T cell lymphoma expressing for instance the IL-2 receptor.

10

## A. THE IMMUNE MODULATOR IM IN FORMULA I

IM stands for an immune modulator that is not a free or conjugated superantigen.

The immune modulator may be a cytokine or a chemokine.

15 Illustrative cytokines are granulocyte macrophage colony stimulating factor (GM-CSF), tumor necrosis factor alpha or beta (TNFalpha or TNFbeta), macrophage colony stimulating factor (M-CSF), granulocyte stimulating factor (G-CSF), IL-1, IL-2, IL-4, IL-6, IL-7, IL-12, IL-15, IL-18 and IGF.

20 Illustrative chemokines are C5a, IL-8, monocyte chemotactic protein 1alpha (MIP1alpha) or monocyte chemotactic protein 1beta (MIP1beta), monocyte chemoattractant protein 1 (MCP-1), monocyte chemoattractant protein 2 (MCP-2), monocyte chemoattractant protein 3 (MCP-3), platelet activating factor  
 25 (PAFR), N-formyl-methionyl-leucyl-phenylalanine (FMLPR), leukotriene B<sub>4</sub> (LTB<sub>4</sub>R), gastrin releasing peptide (GRP), RANTES, eotaxin, lymphotactin, IP10, I-309, ENA78, GCP-2, NAP-2, MGSA/gro, DC-CK1, Flt3L (ectopic domain), fractalkin, PF-4 etc.

30 Another type of immune modulators are those derived from cell membrane anchored receptor/ligand pairs involved in modulation of a triggered immune response, such as costimulation (for instance lymphocyte surface bound receptors and corresponding cell bound ligands). Illustrative examples are members selected  
 35 from the pairs CD40L/CD40, CD28/B7, CTLA-4/B7 etc. B7 includes variants such as CD80 and CD86 with preference for the former.

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good therapy as an optimal dose of C215FabSEA (figure 11). In this system C215FabSEAD227A, which is designed for optimal activity in humans not mice, does only have minor effects (figure 11). At the highest dose, some toxicity of C215FabSEAD227A-Q-hIL2 was encountered, however. In contrast, several therapy experiments indicate that combination of C215FabSEAD227A and C215Fab-Q-hIL2 (8 injections) does also lead to substantially improved therapy of day 3 B16-GA733 tumors in Vb3 TCR transgenic mice when compared to C215FabSEAD227A alone (data not shown). In Vb3 TCR transgenic mice >90 % of T cells react with SEA, as opposed to 10-20 % in normal mice.

Therapy of B16-C215 tumors with IL-2 mutated C215FabSEAD227A-Q-hIL2 proteins. The greater toxicity, and in the case of C215FabSEA-Q-hIL2 lower therapeutic efficacy, of IL2-containing triple fusion proteins may in part be due to "retargeting" of the SEA activity to lymphoid tissues. This retargeting effect is ascribed to the high affinity of IL2 ( $K_d=10$  pM) for its receptor, which is mainly found on T cells in the spleen and other lymphoid tissues. To address this question we have made derivatives of C215FabSEAD227A-Q-hIL2 in which the IL-2 moiety is mutated in order to reduce the affinity for IL2R<sup>+</sup> cells and thus systemic activation. In principle the same approach that was used to improve the therapeutic window for the C215FabSEAD227A protein.

Interaction between IL-2 and its high-affinity receptor is very well studied. The receptor consists of three subunits  $\alpha$ ,  $\beta$  and  $\gamma$ . Cross-linking of  $\beta$  and  $\gamma$  is required for biological activity, whereas the  $\alpha$  subunit is required for optimal binding. Our strategy is to reduce affinity of IL-2 for its high-affinity receptor ( $\alpha\beta\gamma$ ) by eliminating  $\alpha$ -subunit binding, and subsequently reduce, but not eliminate,  $\beta$  and  $\gamma$ -subunit binding as necessary.

Three such mutants of C215FabSEAD227A-Q-hIL2 were designed to eliminate IL2Ra-binding (F42A, F42K) and in addition impair

murine IL-2 indicates that Asp84 and Asp88 of human IL-2 are also implicated in p75 binding (Zurawski et al 1993). This is supported by modelling of the binding between human IL-2 and its receptor (Bamborough et al 1994). The expected reduction in 5 affinity of these mutations is Asp20>Asn88>Asp84.

Combining the mutations in Arg38 and Phe42 with mutations in position 88 and 20 would result in a still lower affinity for IL-2R. Another potent and at the priority date preferred IL-2 mutation is Thr51Pro that gives an IL-2 analogue with a lowered 10 rate of cell internalization and a prolonged duration of its immune modulating effect (Chang et al 1996).

The numbering of amino acid positions is according to Taniguchi et al 1983.

The publications by Grimm et al; Collins et al 1988; Berndt 15 et al 1994; Zurawski et al 1993; Bamborough et al 1994; Chang et al 1996; and Taniguchi et al 1983 are incorporated by reference.

The use of cytokine and chemokine analogues with a reduced affinity for their normal receptors in conjugates as described 20 above will strengthen their targeting to the preselected target cell. It is conceivable that cytokines and chemokines mutated to show a reduced rate of cell internalization upon binding to their respective cell receptor and incorporated into a conjugate according to formula I will results in a prolonged 25 superantigen activity compared to corresponding conjugates with the native form of the immune modulator.

The term immune modulator (IM) thus encompasses any modified form, for instance any mutated form, that is capable of agonizing or antagonizing the effects of the corresponding 30 native form the immune modulator.

#### B. THE SUPERANTIGEN PART SAG IN FORMULA I

Sag in formula I represents a superantigen as defined for free superantigens and under heading "Background..." above, 35 i.e. wild-type superantigens possibly modified, for instance by mutation,

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receptor for IM may be targeted. It is therefore possible that a Sag-IM molecule could be useful for inducing the killing of undesired cells expressing the receptor for IM.

- 5 A C215FabSEA-hIL2 triple fusion protein can be considered a Sag-IM molecule in the event that neither effector nor target cell express the antigen recognized by the C215Fab. Effector cells would be T cells of the right Vbeta subtype. Target cells could e.g. be aberrant hemopoietic cells expressing the IL2  
10 receptor such as those present in certain leukemias or lymphomas.

Exp. A: *In vitro proof-of-concept*: Effector T cells (human T cells repeatedly stimulated with SEA) and target cells (f.ex. human "Raji" B cell lymphoma cells) will be incubated with  
15 C215FabSEA-IL2 triple fusion protein mutated to reduce binding to MHC class I. This is the standard set up for SDCC assays (effector T cells, Raji cells, experimental substance). We have actually found that a C215FabSEA<sub>D227A</sub>-hIL2 protein with severely  
20 reduced affinity for MHC classII has approximately 10-fold higher potency than C215FabSEA<sub>D227A</sub> in killing of Raji cells. An obvious explanation for the increased potency is that the triple fusion protein is presented on IL2 receptors expressed on Raji cells.

25

Exp. B: *In vivo proof-of-concept*: Murine lymphoma models (such as the RBL-5 lymphoma in C57 Bl/6 mice) are well established (Hoglund et al J Exp Med 168, 1469-1474). Targeting of the IL-2 receptor or another IM-R with a Sag-IM protein in such models  
30 could provide proof-of-concept for targeting IM-receptor positive cells *in vivo*.

Sag-IM targeting of IM-R positive cells is complicated by the fact that both effector and target cells frequently express the  
35 receptor for IM. Nevertheless, under certain circumstances this mode of therapy may be efficacious. Factors such as

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At the priority filing preferred superantigens were selected among

1. superantigens (Sag) that exhibit two MHC class II binding sites (for instance staphylococcal enterotoxins A and E),
2. superantigens (Sag) that required Zn-ion for binding to MHC class II (for instance SEA, SEE and SEH),
3. Staphylococcal enterotoxins.

A Sag molecule that is to be incorporated into a conjugate according to the invention does not need to be a functional superantigen, the main issue being that the final conjugate is so by exerting either or both of SADCC and SDCC as outlined above.

#### 15 C. Targeting moiety T in formula I.

T can in principle be any structure that is able to bind to a cell surface structure, preferably a disease specific structure. The structure against which T is directed is usually different (a) from the polymorphic TCR chain epitope to which Sag binds, and (b) from the MHC class II epitopes to which Sag binds. The target-seeking moiety may be selected among interleukins (e.g. interleukin-2), hormones, antibodies including antigen binding fragments of antibodies, growth factors etc. See for instance Woodworth 1993 (hereby incorporated by reference).

The targeting moiety may thus be a protein containing 1, 2, 3 or 4 polypeptide chains.

At the priority date, it was preferred that T was an antibody (full length antibody, Fab, F(ab)<sub>2</sub>, Fv, ScFv (single chain antibody), multiple single chain antibodies (ScFv)<sub>n</sub> and any other antigen binding antibody fragment), including any functionally active truncated form of the antibody forms mentioned above. Other variants are monospecific and bispecific. The antibody may in principle be directed towards any disease associated/specific cell surface structure, for instance structures linked to any of the cancer forms given

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\*Becker et al (1996) Eradication of human hepatic and pulmonary melanoma metastases in SCID mice by antibody-interleukin 2 fusion proteins. Proc. Natl. Acad. Sci. USA 93:2702-2707.

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# E. ATTACHMENT POINTS FOR T, SAG AND IM

Chemical conjugates will typically contain a mixture of conjugate molecules differing in linking positions. The conjugate substance will contain hetero- as well as homo-conjugates.

For recombinant conjugates (fusion proteins) the obtained conjugate substance will be uniform with respect to the linking position. For each individual subunit (T, Sag, IM) the amino terminal is fused to the carboxy terminal of another subunit or vice versa, preferably via an inserted oligopeptide bridge. The combinations in case the conjugate contains one each of T, IM, Sag will be T-IM-Sag, IM-T-Sag, Sag-IM-T, Sag-T-IM, T-Sag-IM, IM-Sag-T (the occurrence of linker structure of B is not shown). In case one or more of the subunits contains two or more polypeptide chains the number of possibilities increase. For T being an antibody Fab fragment the possibilities will be (the oligopeptide linkers B are not shown):

- |                            |                         |
|----------------------------|-------------------------|
| 1. Sag-Fab(light chain)-IM | 2. Fab(light chain)     |
| 20 Fab(heavy chain)        | Sag-Fab(heavy chain)-IM |
| 3. Sag-Fab(light chain     | 4. Fab(light chain)-IM  |
| Fab(heavy chain)-IM        | Sag-Fab(heavy chain)    |
| 25 5. Sag-Fab(light chain) | 6. IM-Fab(light chain)  |
| IM-Fab(heavy chain)        | Sag-Fab(heavy chain)    |
| 7. Fab(light chain)-Sag    | 8. Fab(light chain)-IM  |
| Fab(heavy chain)-IM        | Fab(heavy chain)-Sag    |

30 In further variants the immune modulator and the superantigen may be fused in sequence at any end of any of the chains in the antibody.

At the priority date recombinant conjugates were preferred, with utmost preference for Fab fragments as targeting moiety and linking of the amino terminal of the free superantigen to the first constant domain of the heavy or light antibody chain

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\*Fell et al EP 439095 (patent application).

Fleury S et al (1991) Mutational analysis of the interaction between CD4 and class II MHC: class II antigens. Cell 66:1037-49.

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Hansson J et al (1997) Proc. Natl. Acad. Sci.-U.S.A. 94 (in press).

Kalland et al (1991) WO 9104053 (patent application).  
Pharmaceutical composition that makes cells expressing MHC

10 Class II antigens targets for cytotoxic cells.

Kappler JW et al (1992) Mutations defining functional regions of the superantigen staphylococcal enterotoxin B. J. Exp. Med. 175:387-396

Kappler et al (1993) WO9314634 (patent application). Protective  
15 effects of mutated superantigens.

Kotzin BL et al (1993) Superantigens and their potential role in human disease. Adv. Immunol. 54:99-166.

Lamphear JG et al (1996) Residues near the amino and carboxy termini of staphylococcal enterotoxin E independently mediate  
20 TCRVbeta speccific interactions. J. Immunol. 156: 2178-2185  
(March 15, 1996)

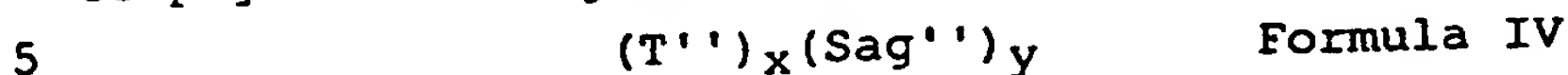
\*Lando PA et al (1993) Co-stimulation with B7 and targeted superantigen is required for MHC class II-independent T-cell proliferation but not cytotoxicity. Immunology 80: 236-241.

25 \*Lando et al (1996) Regulation of superantigen-induced T cell activation in the absence and the presence of MHC class II. J. Immunol. 157:2857-2863.

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mutated, to a reduced affinity and/or reduced rate of internalization as defined above.

Targeted superantigens (T,Sag-conjugates). These conjugates comply with the general formula



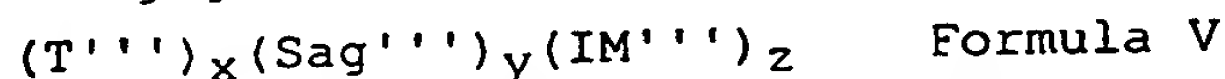
in which T'' and Sag'' are linked together by organic linkers B''. T'', Sag'' and B'' are selected among the same groups of compounds/structures as T, IM and B. x and y are defined in the same way as in formula I (z = 0), with preference for one or  
10 two Sag'' per T'' and conjugate molecule. The attachment points between T'' and Sag'' are as defined for formula I. See also under heading "E. Attachment points....." in which the formulae 1-6 and comments thereto are applicable also to T,Sag conjugates except that IM is omitted from the formula.

15 Conjugates of formula II can be manufactured according to known techniques, i.e. conventional chemical linking or recombinant techniques (fusion proteins), with preference for the former. See for instance Dohlsten et al WO9201470; Abrahmsén et al WO 9601650, Antonsson et al WO PCT/SE97/00537.

20

Third major aspect of the invention: Conjugates containing a modified immune modulator.

These novel conjugates complies with the formula:



25 where T''' and Sag''' are selected among the same compounds as T and Sag for formula I. IM''' is an immune modulator that has been modified, for instance by mutation, to exhibit a lowered affinity to its cell membrane anchored receptor and/or a lowered rate of internalization via binding to its receptor  
30 (compared to corresponding native forms). IM'' is preferably a cytokine or a chemokine. See further under heading "A. The immune modulator IM in formula I". One important immune modulator for this aspect of the invention is modified IL-2. x, y and z are defined in the same way as in formula I.

35 In a first subaspect of conjugates according to formula V, T''', Sag''' and IM''' are always present (all x, y and z > 0),

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\*Terman et al (1993) WO9324136 (patent application). Tumor killing effects of enterotoxins and related compounds.

Woodworth (1993) Preclinical and Clinical development of Cytokine toxins presented at the conference "Molecular approaches to cancer Immunotherapy", Ashville, North Carolina, November 7-11, 1993.

Wootton et al (1989) Prot. Eng. 2:535-543.

\*Zurawski et al (1993) EMBO J. 12:5113-.

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proteinic targeting moieties. The techniques are well-known in the art.

The main host cell for large scale recombinant production of the inventive conjugates between a superantigen and an immune modulator (fused forms as well as non-conjugated forms) is E. coli. This host provides for in principle two routes: intracellular production and secretion. The latter variant is preferred because it offers purification of correctly folded proteins from the periplasma and from the culture medium. The above does not exclude that it is possible to produce active conjugates also in other host cells, e.g. eukaryotic cells, such as yeast or mammalian cells. Preliminary results have so far indicated that eukaryotic cells, such as mammalian cells, may be preferred for incorporating immune modulators interacting with CD28, for instance B7 and its analogues.

#### THE FOURTH ASPECT OF THE INVENTION: GENE CONSTRUCTS ENCODING THE NOVEL INVENTIVE CONJUGATES.

A fourth aspect of the invention is a recombinant nucleic acid molecule, preferably DNA, such as cDNA, or RNA, encoding a superantigen and an immune modulator as defined above, with preference for IL-2, IL-7, IL-12, IL-15, IL-18, RANTES, ectopic domain of CD80, ectopic domain of CD86, and Flt3L and their analogues as defined above. In this aspect of the invention, the nucleic acid typically should contain regulatory control sequences such as translation regulatory sequences, origin of replication, secretory signal sequences either for one or both of the immune modulator and the superantigen, etc that are compatible with the host cell in which the immune modulator and the superantigen are to be expressed. The region between the part sequences encoding the superantigen and the immune modulator may comprise a sequence encoding a ribosome entry sites such as in bicistronic gene constructs. The latter will allow separate expression of each polypeptide chain comprised within the conjugate. In case of multichain conjugate combinations containing IM, Sag, targeting moiety conjugate and

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4. The method according to claim 2, characterized in that alternative b is used, with the possibility that the targeting moiety in the immune modulator conjugate may differ from the targeting moiety in the superantigen conjugate.
5. The method according to claim 2, characterized in that alternative c is used.
6. The method according claim 2 characterized in that alternative e is used and in that IM and T is common, for instance a cytokine receptor, such as IL-2, for targeting the conjugate cells carrying the receptor.
7. The method of anyone of claims 1-6, characterized in that the cells are inactivated in vivo in an individual suffering from a disease associated with the target cells, for instance a cancer.
8. The method of anyone of claims 1-7, characterized in that the targeting moiety is an antibody, preferably an antigen binding fragment thereof, such as Fab or Fab<sub>2</sub>-fragment or a single chain antibody.
9. The method of anyone of claims 1-8, characterized in that the superantigen Sag is modified, for instance by mutation,
- a. to have a decreased ability to bind to MHC class II antigen compared to the corresponding wild type superantigen;
  - b. to have a decreased seroreactivity in human sera compared to the corresponding wild-type superantigen;
  - c. to have a decreased immunogenicity in human compared to the corresponding wild-type superantigen;
  - d. to be a chimera between two or more free superantigens.

See further above in the context of the inventive methods. In case the compositions contain two active components (b-d above) the composition may allow for keeping the components apart up to the occasion for administration.

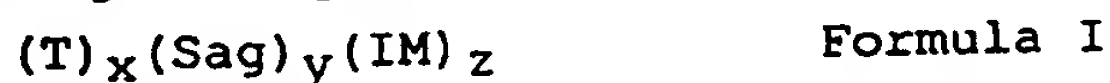
- 5 The compositions may be in the form of a lyophilized particulate material, a sterile or aseptically produced solution, a tablet, an ampoule etc. Vehicles such as water (preferably buffered to a physiologically acceptable pH value by for instance PBS) or other inert solid or liquid material  
10 may be present. In general terms the compositions are prepared by the conjugate, possibly in combination with an unconjugated active component, being mixed with, dissolved in, bound to, or otherwise combined with one or more water-soluble or water-insoluble aqueous or non-aqueous vehicles, if necessary  
15 together with suitable additives and adjuvants. It is imperative that the vehicles and conditions must not adversely affect the activity of active components as defined in a-e above.

Normally the superantigens (SAG) to be used in the invention  
20 will be sold and administered in predispensed dosages, each one containing an effective amount of SAG that, based on the result now presented, is believed to be within the range of 1pg - 50 mg. The exact dosage will vary from case to case depending on the patient's weight and age and pretiter of antibodies  
25 specific for the SAG used, route of administration, type of disease, target-seeking moiety, superantigen, linkage (-B-), immune modulator etc.

An important factor to account for in determining the dose for a combination to be used in the inventive method is that  
30 superantigens and immune modulators exert optimal dose ranges. A too low dose will result in no or a suboptimal effect and a too high dose will give unacceptable side effects such as toxicity that may be lethal. Thus it has to be emphasized the broad range given above is an attempt to encompass all ranges  
35 possible for all variants of the inventive method. Thus, each specific combination according to the inventive method has a

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16. A superantigen conjugate complying with the formula



- 5 a. T is a targeting moiety, Sag corresponds to a free superantigen, IM is an immune modulator that is not a superantigen and T, Sag and IM are linked together via organic linkers B that may be different or equal within one and the same conjugate molecule;
- 10 b. x, y and z are integers that typically are selected among 0-10, such as 0-5, and represent the number of moieties T, Sag and IM, respectively, in a given conjugate molecule, with the provision that  $y > 0$  and also one or both of  $x$  and  $z > 0$ ;

- 15 17. The superantigen conjugate of claim 16, characterized in that it is a fusion protein in which all x and y and z are integers 1-3, with preference for 1-2, and typical relations between x, y and z being selected among  $x = y = z$ ;  $x = y = 0.5z$ ;  $x = 0.5y = 0.5z$ ; and  $x = 0.5y = z$ .

- 20 18. The superantigen conjugate of claim 16, characterized in that it is a fusion protein, the targeting moiety is absent ( $x = 0$ ) and y and z are integers 1-3, with preference for 1-2, and preferred relations between x and y being selected among:  $x = y$ ;  $x = 0.5y$ ,  $0.5x = y$ ;  $x = 1/3y$  and  $1/3x = y$ .

- 25 19. The superantigen conjugate of claim 16, characterized in having the formula:



in which  $y = z = 1$ .

- 30 20. The superantigen according to claim 16-19, characterized in the targeting moiety is as defined in claim 8, and/or the superantigen moiety as defined in anyone of claims 9-10 and/or the immune modulator moiety is as defined in anyone
- 35 of claims 11-15.

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Figure 1. FACS analysis of CHO-CD28 cells stained with CD80-C215Fab, CD80-C215Fab-SEAm57 or C215Fab-SEA followed by incubation with anti-mouse kappa chain mAb labeled with PE. The staining were done at 4°C without any washes.

5 Figure 2. FACS analysis of Colo205 cells stained with CD80-C215Fab, CD80-C215Fab-SEAm57 or C215Fab-SEA followed by incubation with anti-mouse kappa chain mAb labeled with PE. The staining were done at 4°C with three washes between each staining step.

10 Figure 3. Proliferation. T cells were incubated with Colo205 cells and 4uM C242Fab-SEA and varying amounts of CD80-C215Fab for 4 days after which the incorporated  $^3\text{H}$  - thymidine was counted. The activity obtained without any CD80-C215Fab was 20039cpm +/- 1750.

15 Figure 4. IL-2 production. T cells were incubated with Colo205 cells and 4uM C242Fab-SEA and varying amounts of CD80-C215Fab for 4 days after which the supernatant was harvested and the amount IL-2 was determined. The amount IL-2 obtained without any CD80-C215Fab was 2849 pg/ml .

20 Figure 5. Proliferation. T cells were incubated with Colo205 cells and varying amounts of CD80-C215Fab-SEAm57 or C215Fab-SEAm23 for 4 days after which the incorporated  $^3\text{H}$  -thymidine was counted.

25 Figure 6. IL-2 production. T cells were incubated with Colo205 cells and varying amounts of CD80-C215Fab-SEAm57 or C215Fab-SEAm23 for 4 days after which the supernatants were harvested and the IL-2 contend determined.

30 Figure 7. Proliferative capacity of human blood T cells incubated for 7 days with the indicated proteins and irradiated, transfected CHO cells (for presentation of SEA) .

35 Figure 8. Simultaneous administration of targeted SEA and IL2 leads to enhanced T cell activation in vivo. Cytotoxicity against SEA-coated MHC class II<sup>+</sup> Raji cells of splēenocytes from mice treated with 1 or 3 injections of C215FabSEA (FS), C215Fab-Q-hIL2 (FI), combination of the

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in which  $y = z = 1$ .

25. A DNA molecule encoding a superantigen and an immune modulator, such as IL-2, that is not a superantigen.
- 5
26. The DNA molecule of claim 25, characterized in that it is in the form of a biscistronic construct in which
- 10
- a. a first cistron contains a sequence I encoding a polypeptide I comprising an unconjugated superantigen (Sag) that possibly is modified as defined in claims 9-10, and
- b. the other cistron contains a sequence II encoding a polypeptide II comprising the immune modulator that possibly is modified as defined in claim 11-15.
- 15
27. The DNA molecule of claim 26 characterized in that either or both of sequences I and II are fused to a respective sequence encoding at least a part of an antibody such that polypeptides I and II can associate and form a triple fusion
- 20
- comprising a free superantigen, an immune modulator, and an antibody.
28. The DNA molecule of claim 25, characterized in that the superantigen is a unconjugated superantigen and that the
- 25
- sequence encoding the superantigen is fused to the sequence encoding the immune modulator, possibly via a sequence encoding an oligopeptide linker.

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**Summary:** CD80-C215Fab and CD80-C215Fab-SEAm57 fusion proteins have been constructed to contain the extracellular domain of human CD80. The fusion proteins were produced in mammalian cells, and tested for binding to CD28 using CHO cell transfectants and C215 antigen using Colo205 cells. Both fusion proteins bound to CD28 and C215 antigen, the later binding being 100-fold reduced compared to C215Fab-SEA. Since CD80 is linked to the N-terminal part of the L-chain it is possible that the CD80 moiety interferes with the C215Fab binding. Both fusion proteins costimulate SAG activated human T cells showing that the soluble CD80 retains its biological function.

#### MATERIAL AND METHODS

**Recombinant DNA techniques and enzymes:** Plasmid DNA preparations and other operations were performed essentially according to Sambrook et al. (Sambrook et al 1989). E. coli HB101 (Boyer et al 1969) was used as the host strain. Restriction endonucleases and the Klenow fragment of DNA polymerase I were obtained from Boehringer Mannheim or New England Biolabs, and used according to the suppliers recommendations. Taq-polymerase was obtained from Perkin Elmer. cDNA was made from the total RNA using the GeneAmp RNA PCR kit (Perkin-Elmer). Oligonucleotides were synthesized on a Gene Assembler (Pharmacia Biotech AB) or an ABI 392 DNA/RNA synthesizer (Applied Biosystems), and purified by reversed phase chromatography on the FPLC system (Pharmacia Biotech). Sequencing was done according to the dideoxy chain-termination principle (Sanger et al 1977) using Applied Biosystems Taq DyeDeoxy Termination Cycle Sequencing Kit and the products separated and detected on a DNA sequencer ABI 373A (Applied Biosystems). Bacteria harboring different plasmids were selected on plates containing 2 X YT and 15 g agar base per liter, supplemented with 70 mg/L kanamycin, or 100 mg/L ampicillin. The liquid broth was 2 X YT (per liter: 10 g yeast extract (Difco), 16 g tryptone (Difco) and 5 g NaCl).

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## FACS analysis of CHO-CD28 cells

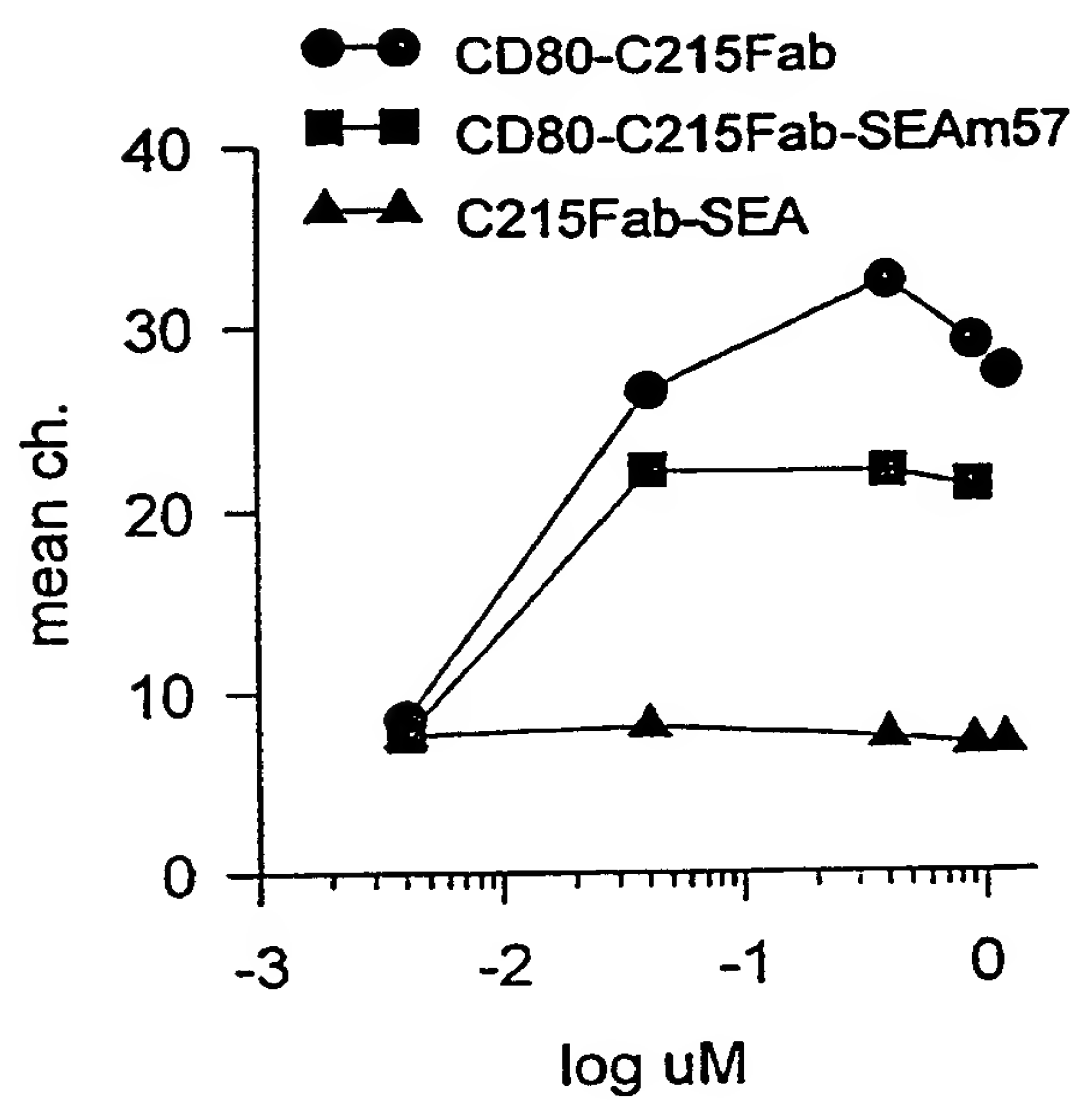


Figure 1

The genes encoding a Fab fragment containing the variable domains of the murine antibody C215 were assembled as described previously (Dohlsten et al 1994). Cloning and mutagenesis of the staphylococcal enterotoxin A (SEA) gene yielding the replacements F47A and D227A has been described previously (Abrahmsén et al 1995). Three other mutations were introduced in the SEA gene using the primers LAKQ88-93 (all oligonucleotides used are compiled in Table I) to obtain SEA mutant 57. LAKQ5 and LAKQ7 were used in RT-PCR to introduce a Kozak box upstream, and to clone the gene encoding signal peptide and the extracellular part of human CD80 from human spleen total RNA. The nucleotide sequence was found to correspond to the gene bank sequence of CD80 (Accession number M27533). Two variants of the CD80 gene were made, having different cloning sites at the 3'-end: in separate PCRs the primers LAKQ30 and LAKQ108 were used to obtain a BssHII or a MroI site, respectively. A gene fusion encoding a CD80 fused before the kappa chain by a Q-linker (Wooton et al 1989), was constructed by inserting the DNA linker LAKQ37/38 BssHII-Esp3I, between the relevant CD80 gene and a DsaI site directly preceding the kappa gene. The plasmid pKGE987 was obtained by inserting the gene fusion encoding CD80-(Q-linker)-kappa, preceded by the CD80 signal peptide into a vector, which in addition to a CMV promoter and a poly A tail contains a neomycin gene to be used for selection of transformants. The last version of the CD80 gene was used to construct a gene fusion where it precedes the Fd-SEA mutant 57 gene fusion: a DNA fragment (LAKQ117/118) encoding a Q-linker was inserted between a MroI site in the CD80 gene and a PstI site at codon 4 and 5 in the C215 VH gene. This gene fusion was inserted in a second CMV promoter vector to yield the plasmid pMB189, thus encoding the CD80 signal peptide and extracellular portion followed by Fd and SEA mutant 57, connected by the three residue spacer GGP. In the plasmid pKGE961 the Fd gene has been inserted following a signal sequence (derived from another murine VH gene). The plasmid pMB156 encodes the native kappa

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## Proliferation

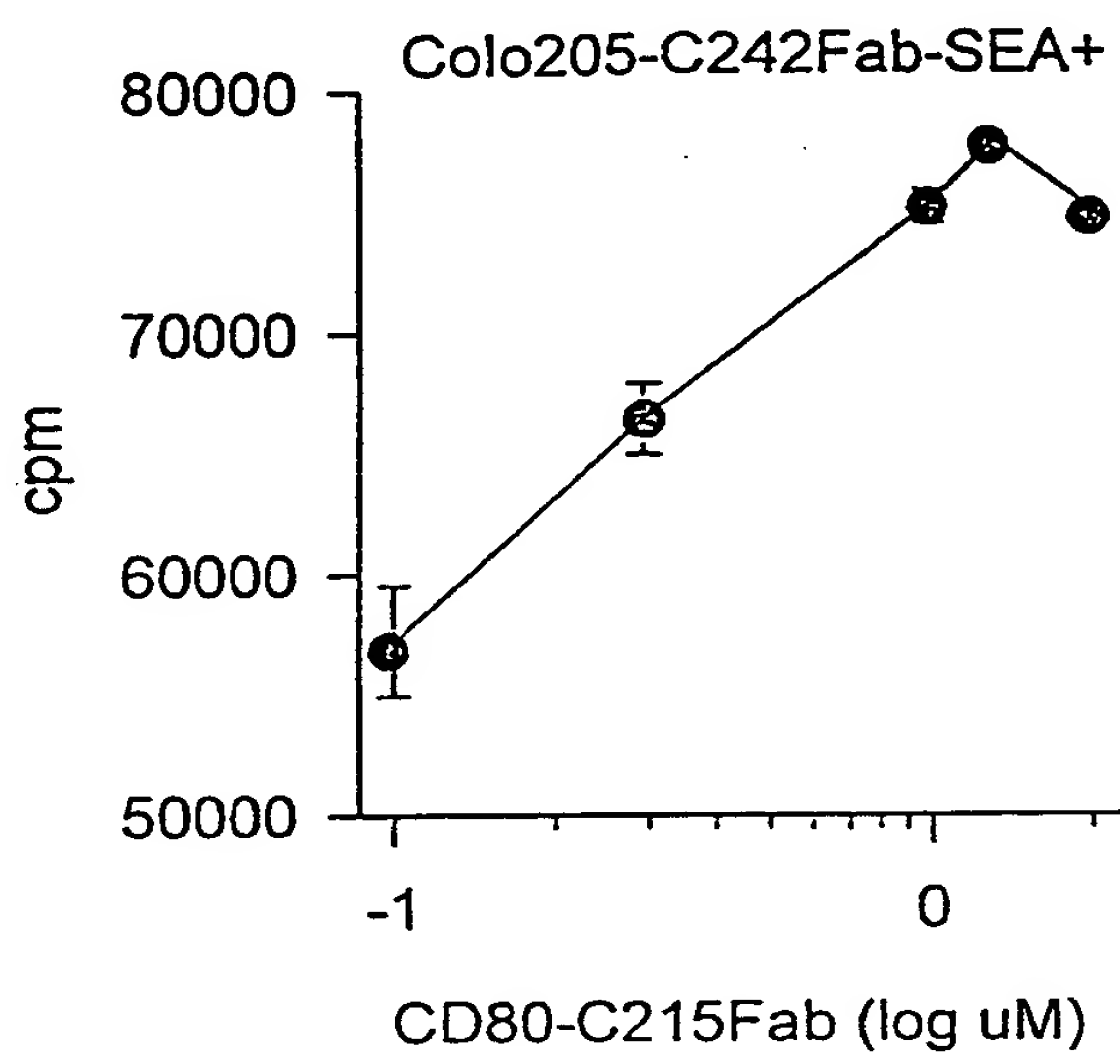


Figure 3

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antigen expression levels. The human colon carcinoma cell line Colo205 was obtained from ATCC. All cell lines were free of mycoplasma.

**T lymphocyte proliferation assay.** T cells were obtained from human peripheral blood mononuclear cells (PBM) as previously described (Lando et al 1996) by negative selection panning with CD57, HLA-DR4, CD14 and CD56 mAbs. All tests on T cells were performed with  $0.1 \times 10^6$  cells/well in 200  $\mu$ l volumes, using flat-bottomed 96-well plates (Nunc, Roskilde, Denmark). DNA-synthesis was studied after exposure of cultures to [ $^3$ H]-thymidine [ $^3$ H]TdR (0.5mCi/well) as described earlier (10). **Analysis by flow cytometry.** Flow cytometric analysis and sorting were performed according to standard setting on a FACStar<sup>Plus</sup> flow cytometer (Becton Dickinson, Mountain View, CA). Due to the low affinity of CD80 to CD28 staining of CHO-CD28 cells with CD80-C215Fab fusion proteins were done omitting washes of the cells. **Cytokine assay.** The production of IL-2 was analyzed using a IL-2 ELISA kit ( huIL-2 DuoSet, Genzyme).

20

## Results.

**Description of the CD80-Fab fusion proteins.** The Fab moiety is of murine IgG1/k isotype although it contains the variable domains of the IgG2A/k monoclonal antibody C215 (Dohlsten et al 1995). The tripeptide sequence GGP follows the inter-chain disulphide forming cysteine in the CH1 domain. In the CD80-C215Fab-SEAm57 triple fusion protein, this functions as a spacer between Fd and a mutant of staphylococcal enterotoxin A (SEA; Betley et al 1988), having five substitutions. The replacements F47A and D227A were introduced to diminish affinity for MHC class II (Abrahmsén et al 1995), and the replacements N102Q, N149D and T218V were introduced to avoid fortuitous glycosylation when produced in eukaryotic cells. These latter replacements were selected with the aid of the X-ray structure (Sundström et al 1996). The final penta mutant was designated SEA mutant 57. Both fusion proteins contain the

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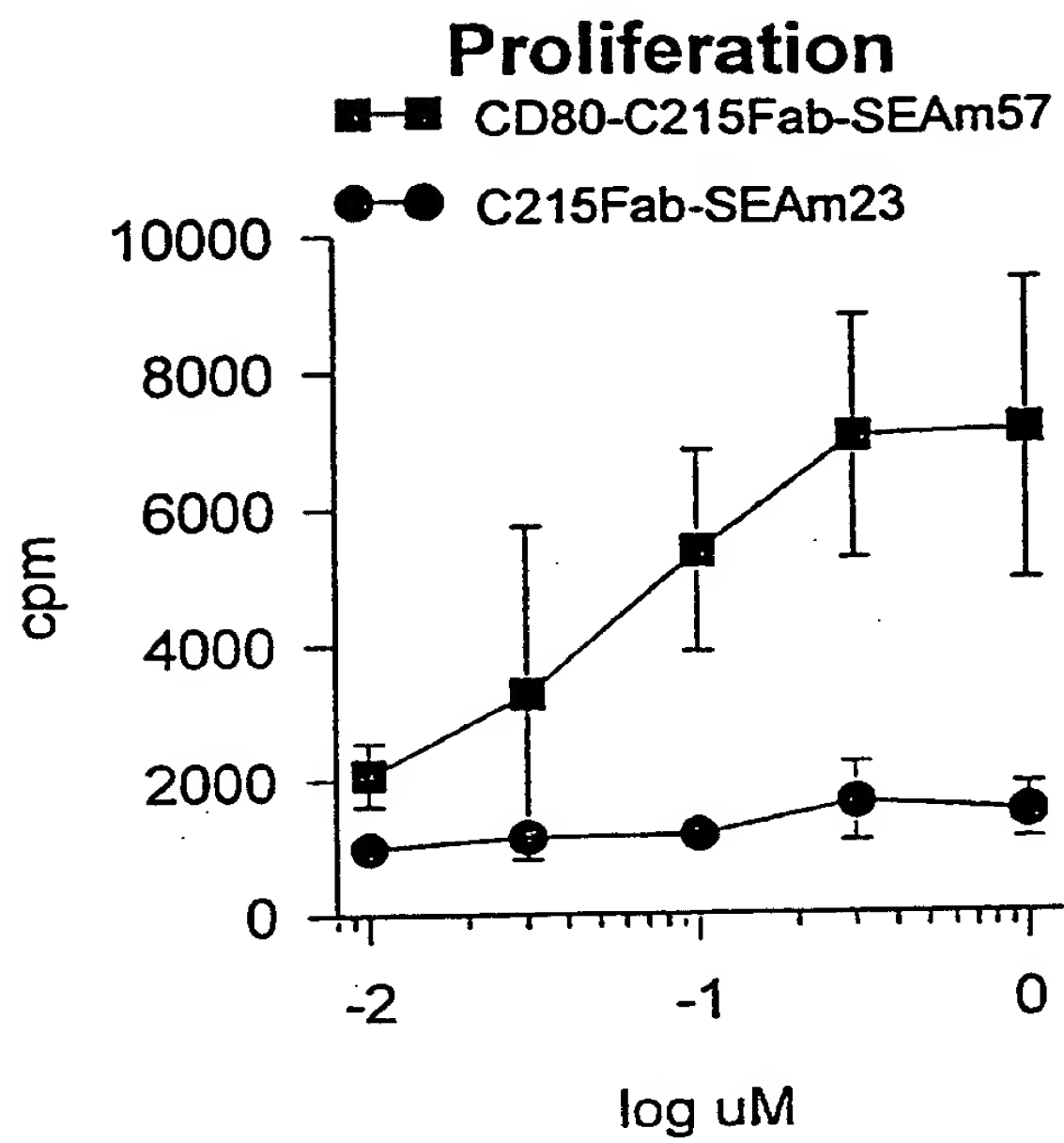


Figure 5

To determine the biological activity of the fusion proteins they were tested for costimulation of superantigen activated T cells.

**Proliferation:** T cells were incubated with Colo205 cells and 4uM C242Fab-SEA and varying amounts of CD80-C215Fab for 4 days after which proliferation measured as incorporated  $^3\text{H}$  - thymidine was counted.

**IL-2 production:** T cells were incubated with Colo205 cells and 4uM C242Fab-SEA and varying amounts of CD80-C215Fab for 4 days after which the supernatant was harvested and the amount IL-2 was determined.

**Results (figures 3-4):** CD80-C215Fab costimulated the C242Fab-SEA induced activation of the T cells in a dose dependent manner both seen as proliferation and IL-2 production.

15

**Triple Fusions.** Costimulation of superantigen activated T cells.

To test the biological activity of the triple fusion protein, purified T cells were incubated with C215Fab-SEAm23 (m23 being the same SEA mutant affecting MHC class II binding that was used in the triple fusion protein, i.e. Phe47Ala/Asp227Ala) or CD80-C215Fab-SEAm57 presented on Colo205 cells. Proliferation: The incorporated  $^3\text{H}$  -thymidine was counted after 4 days. IL-2 production: The supernatants were harvested and the IL-2 content determined after 4 days.

**Results (figures 5-6):** The triple fusion protein induced T cell activation and IL-2 production when presented on Colo205 cells. No such activity was seen with the C215Fab-SEAm23 indicating the importance of costimulation by CD80 for activation. Due to the lower binding affinity of the triple fusion protein (50-100x lower than that of C215Fab-SEA, see FACS data), the actual amount of C215Fab-SEAm23 bound to cells is likely to be substantially higher than that of the triple fusion protein.

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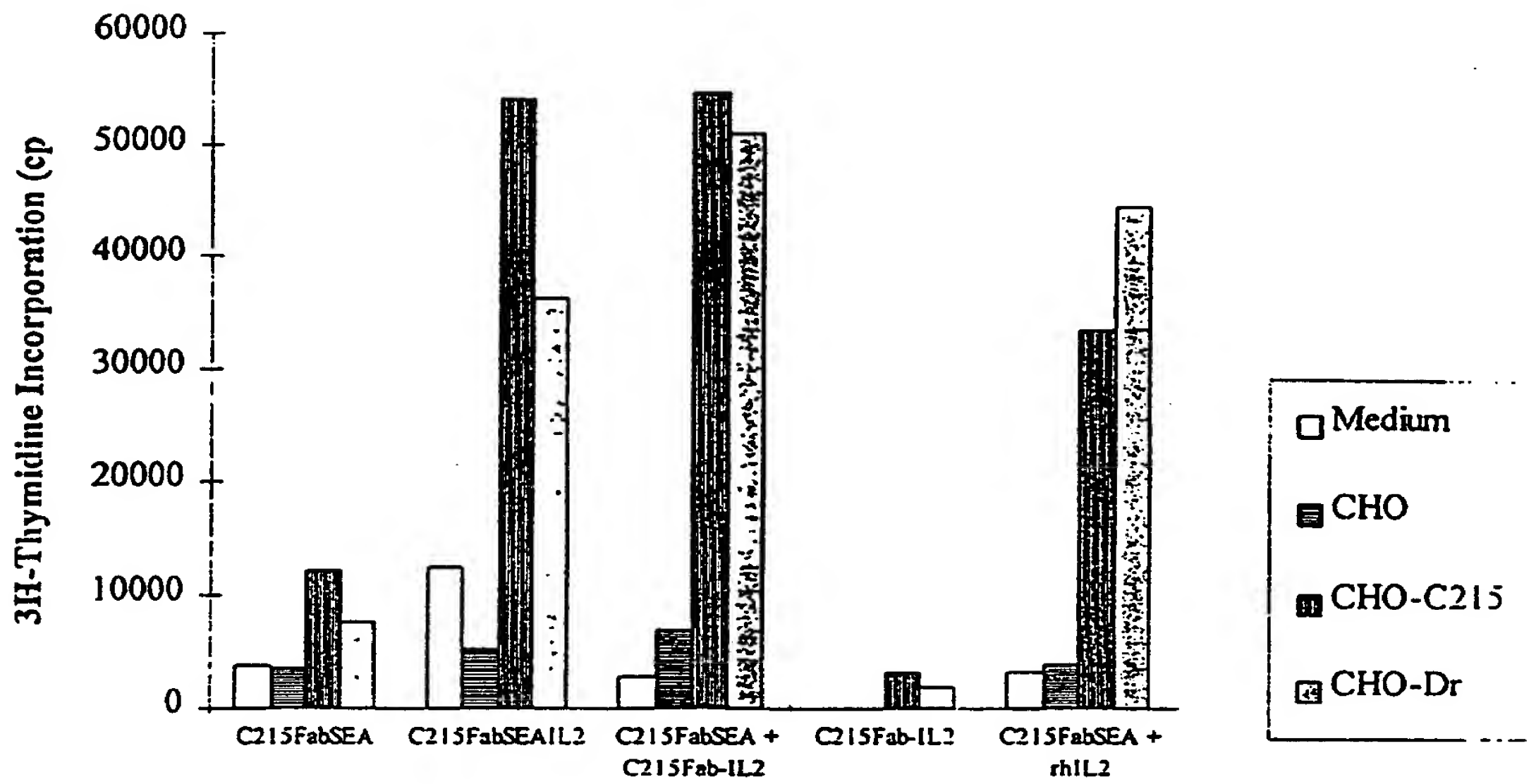


Figure 7

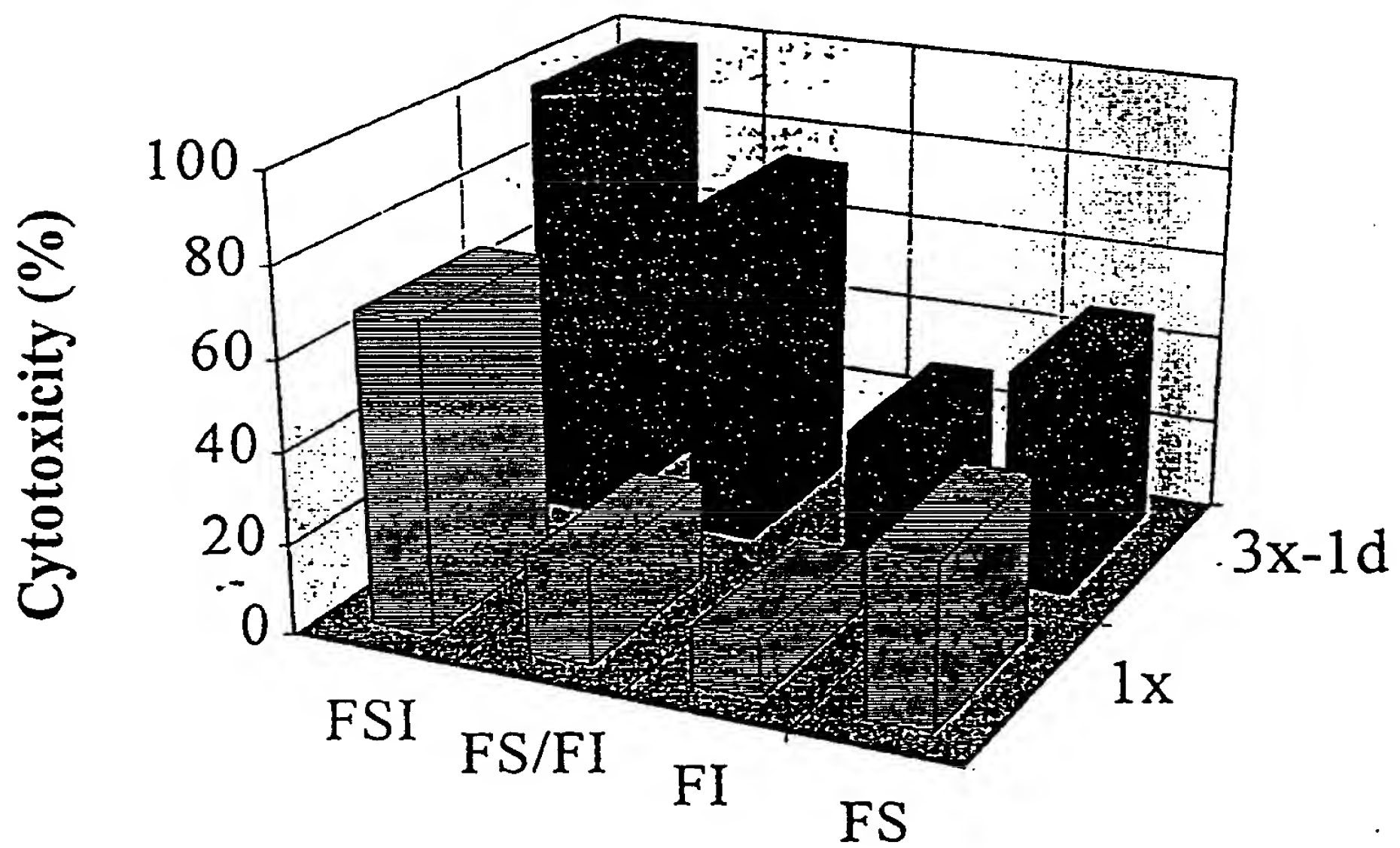


Figure 8

5'-CCG AAT TCG CTA GCT TAT CAA GTT AGT GTT GAG ATG  
AT-3' (SEQ ID NO 17)

Expression of the fusion proteins in fermenter. Fusion  
5 proteins were expressed in the *E. coli* K-12 strain UL 635  
(*xyl*-7, *ara*-14, *T4<sup>R</sup>*, *deltaompT*) using a plasmid with a  
kanamycin resistance gene and *lacUV5*-promoter. Bacteria from  
frozen stock were incubated at 25°C for approximately 21 h in  
shaker flasks containing (g/l) ( $\text{NH}_4$ )<sub>2</sub>SO<sub>4</sub>, 2.5; KH<sub>2</sub>PO<sub>4</sub>, 4.45;  
10 K<sub>2</sub>HPO<sub>4</sub>, 11.85; sodium citrate, 0.5; MgSO<sub>4</sub>•7 H<sub>2</sub>O, 1; glucose  
monohydrate, 11, 0.11 mM kanamycin and 1 ml/l trace element  
solution (Forsberg et al., 1989), however without Na<sub>2</sub>MoO<sub>4</sub>•2  
H<sub>2</sub>O. The cells were grown to an OD<sub>600</sub> of 1-2 and 450 ml  
culture medium was used to inoculate a fermenter (Chemap,  
15 Switzerland) to a final volume of 5 l. The fermenter medium  
contained (g/l) ( $\text{NH}_4$ )<sub>2</sub>SO<sub>4</sub>, 2.5; KH<sub>2</sub>PO<sub>4</sub>, 9; K<sub>2</sub>HPO<sub>4</sub>, 6; sodium  
citrate, 0.5; glucose monohydrate, 22; MgSO<sub>4</sub>•7 H<sub>2</sub>O, 1; 0.11  
mM kanamycin; 1 ml adecanol (Asahi Denka Kogyo K.K, Japan)  
and 1 ml/l trace element solution. The pH was kept at 7.0 by  
20 titration with 25 % ammonia, the temperature was 25°C and  
aeration with atmospheric air 5 l/min. The partial pressure  
of dissolved O<sub>2</sub> was controlled to 30 % by increasing  
agitation from 300 to 1000 rpm during batch phase and  
regulating the feed of 60 % (w/v) glucose during fed batch  
25 phase. Product formation was induced at an OD<sub>600</sub> of 50 by  
adding 0.1 mM isopropyl beta-D-thiogalactopyranoside, IPTG.  
After fermentation, the cells were removed by centrifugation  
at 8000xg for 40 min at 4°C. The clarified medium was either  
analysed and purified directly or stored at -20°C.

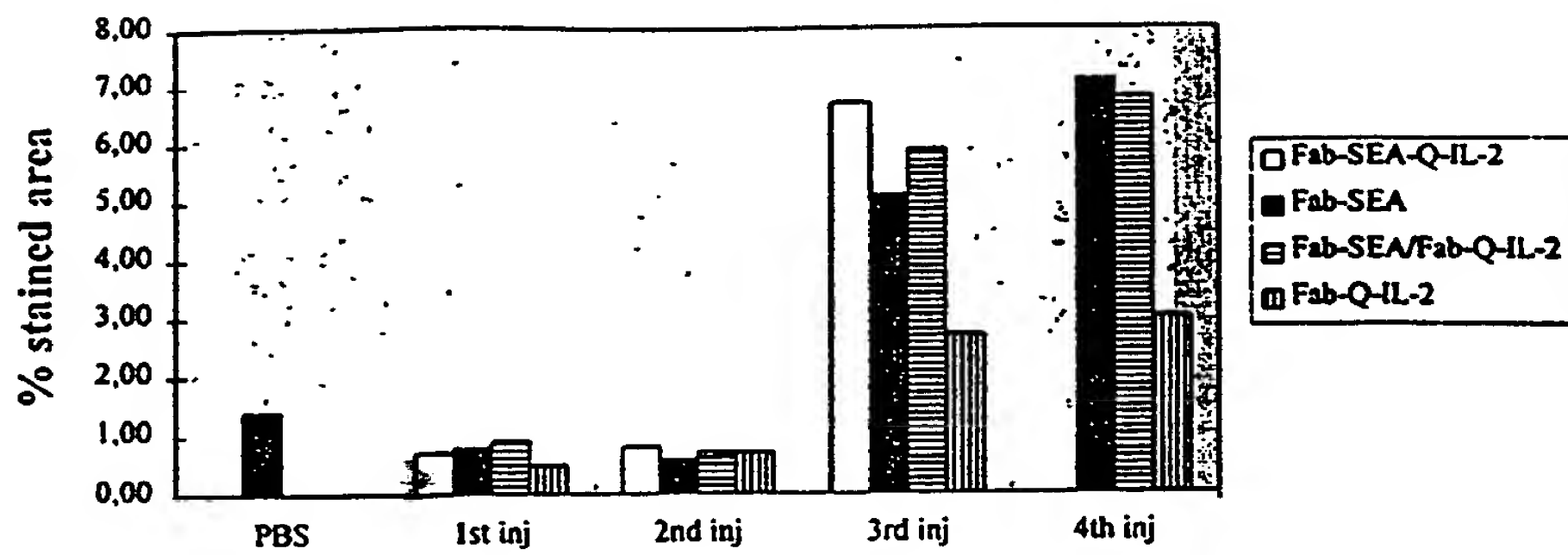
30

Purification of fusion proteins. DNA present in the clarified  
medium was removed using precipitation with 0.19 %  
polyethylenimine and 0.2 M NaCl during 30 min (Atkinson and  
Jack, 1973). After centrifugation as above, the supernatant  
35 was collected and the NaCl concentration adjusted to 0.5 M.  
This medium was applied to a Protein G Sepharose column

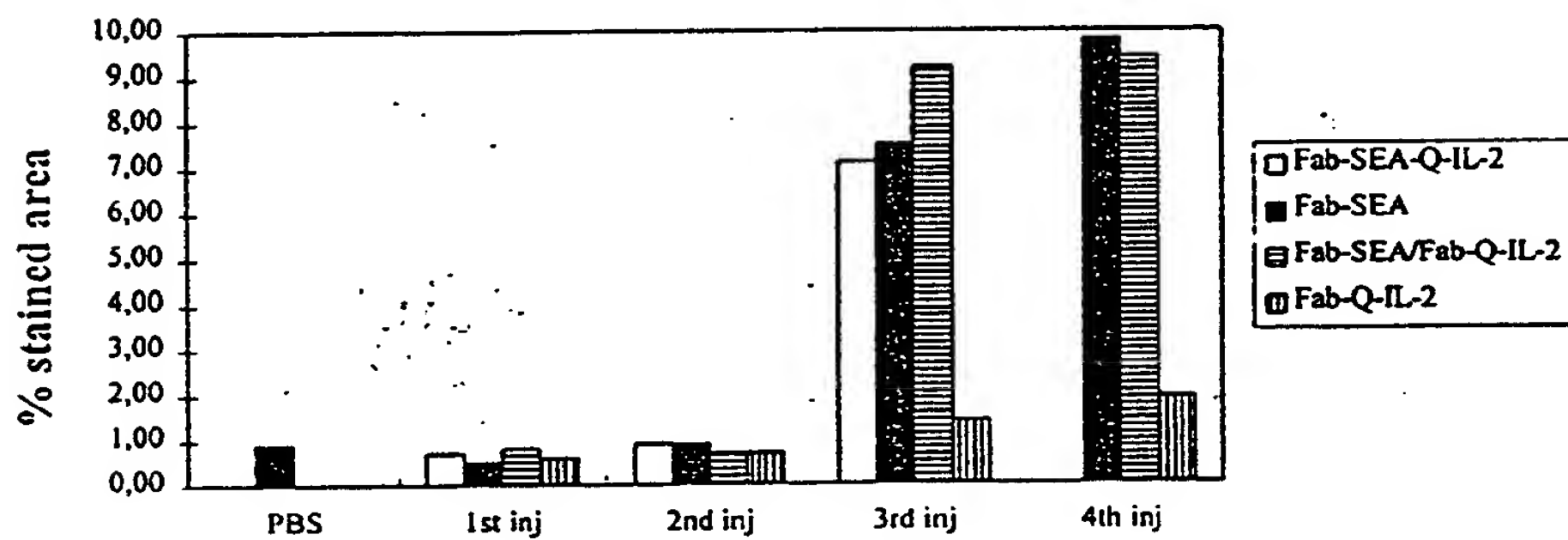
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CD4 in lung:



CD8 in lung



IL2R $\alpha$  (CD25) in lung

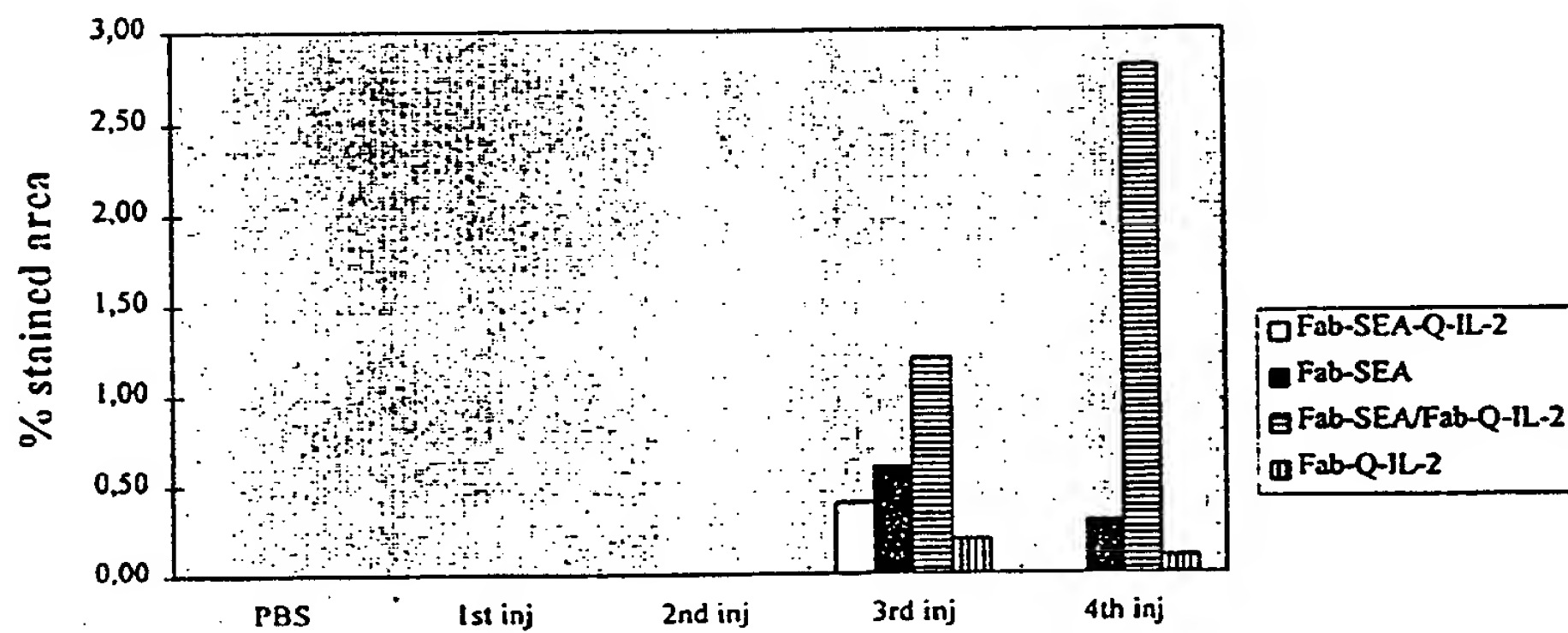


Figure 10

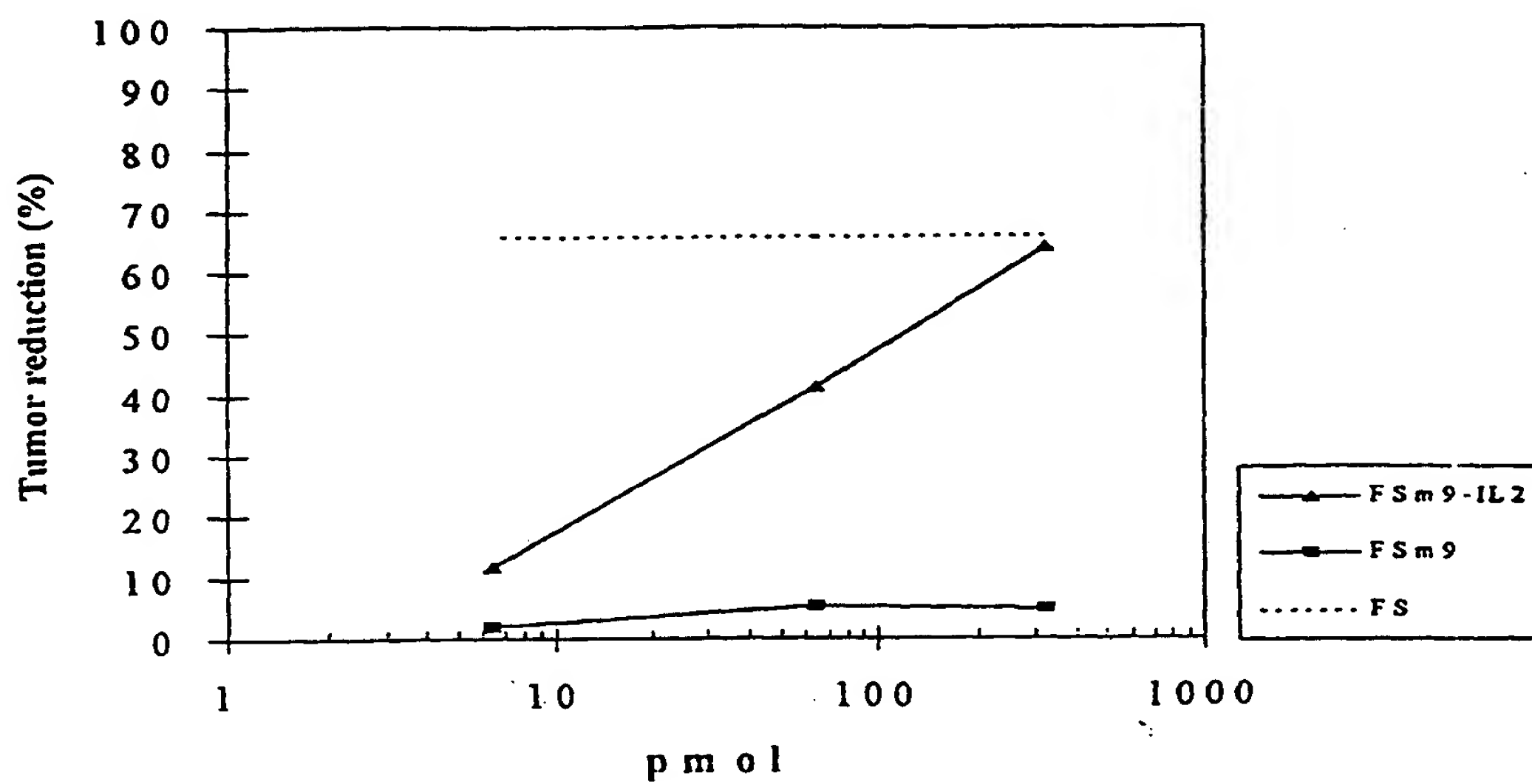


Figure 11

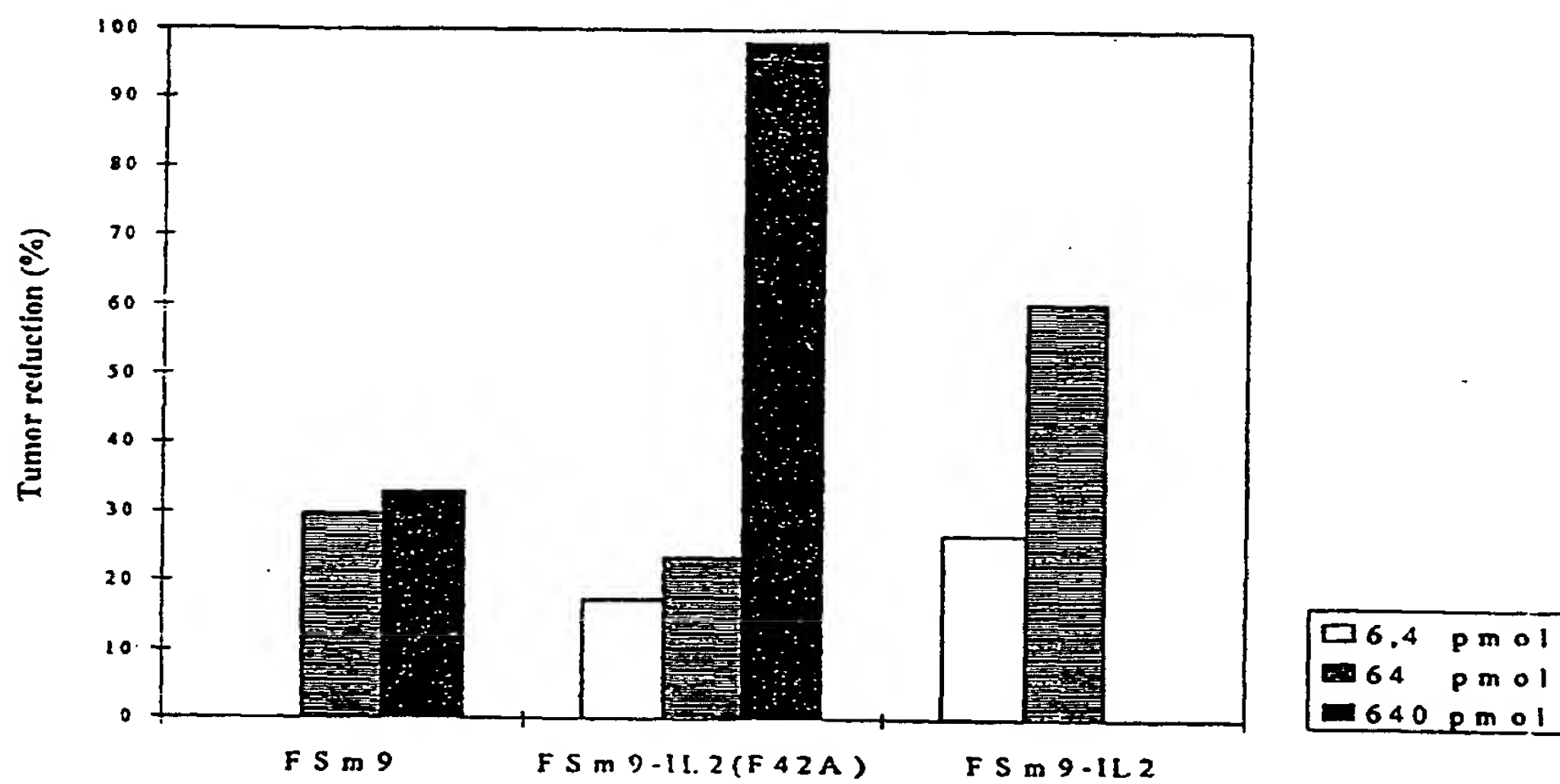


Figure 12

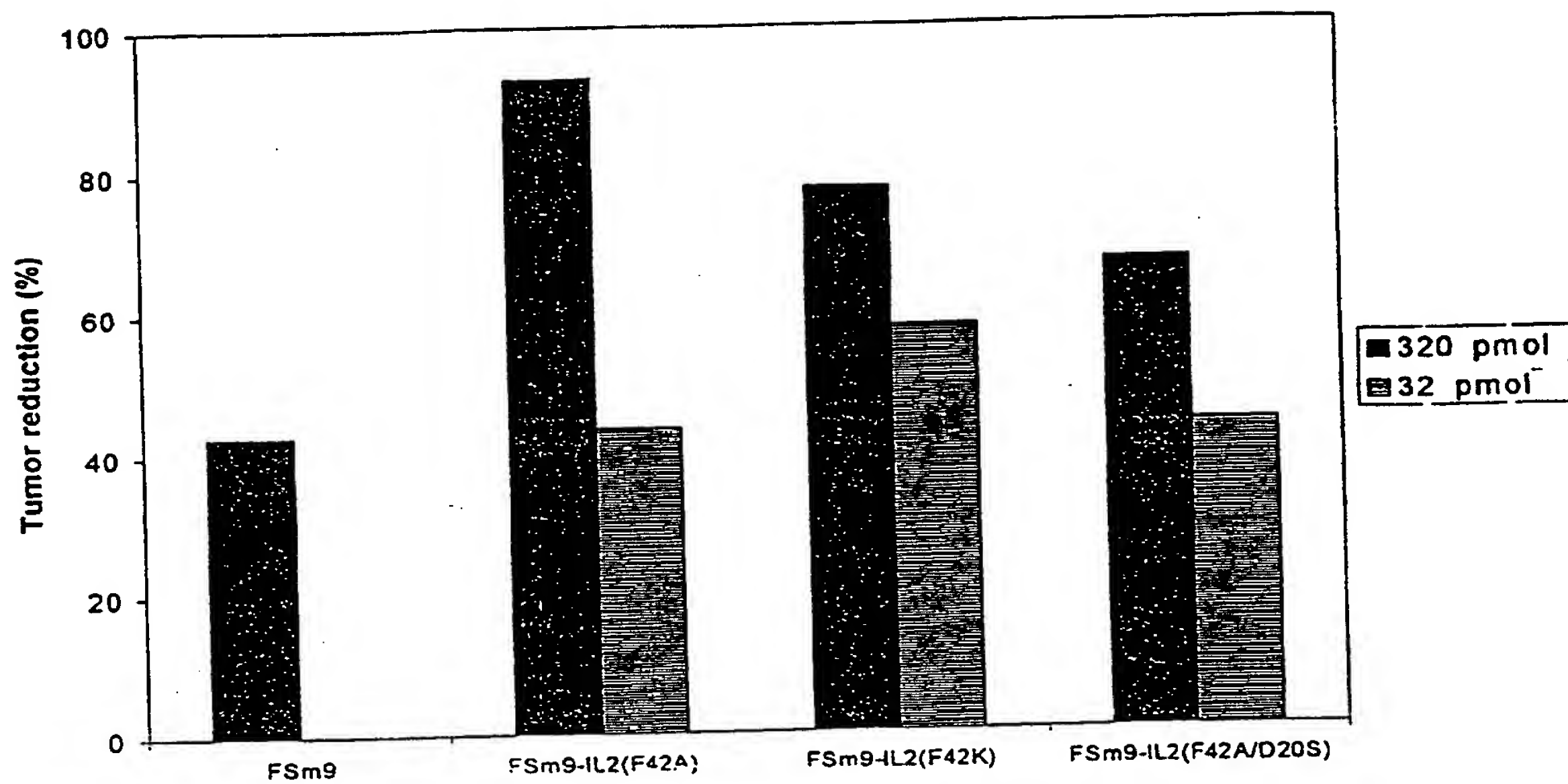


Figure 13

